INTEGRATED
FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION

BOGUE BANKS, CARTERET COUNTY

NORTH CAROLINA

APPENDIX L

Draft Fish and Wildlife Coordination Act Report

US Army Corps of Engineers
Wilmington District

DRAFT FISH AND WILDLIFE COORDINATION ACT REPORT
BOGUE BANKS SHORE PROTECTION PROJECT
CARTERET COUNTY, NC

Raleigh Ecological Services Field Office
U.S. Fish & Wildlife Service

Under the supervision of
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November 2002

EXECUTIVE SUMMARY

Bogue Banks is a complex barrier island composed of old beach ridges and dune fields (Moslow and Heron 1994, Riggs 2002). The island is not dominated by overwash processes, instead having some of the highest interior elevations of any North Carolina barrier island. The maritime forest and freshwater wetland communities within this high dune ridge and swale topography are of high value (resource category of 2) to fish and wildlife resources. The estuarine shoreline and Bogue Sound also provide high value (resource category of 2) to fish, shellfish, and wildlife resources in the project area, containing waters designated as Outstanding Resource Waters (ORW) in the western portion of Bogue Sound and as a Habitat Area of Particular Concern (HAPC) throughout the sound. Bogue Inlet to the west is of high value (resource category of 2) due to its scarcity as a comparably undisturbed tidal inlet in North Carolina. Beaufort Inlet to the east of the island is disturbed by a deep navigational channel and regular maintenance dredging, reducing its value to a more abundant, high to medium value (resource category of 3) to fish and wildlife resources. The nearshore and offshore marine areas are of high value (resource category of 2) to commercially and recreationally important fisheries, hardbottoms, artificial reefs, marine mammals, sea turtles and a productive benthic community.

A dredge and fill project to stabilize the oceanfront shoreline of Bogue Banks is more likely to be successful than for most other locations in North Carolina. The habitat value of the potential beach fill area is medium to low (resource category of 4), and several dredge and fill projects are occurring already. Relatively low erosion rates and high island elevation create a more durable system for beach nourishment than other low-lying, overwash-dominated barrier islands in the state.

Although adverse environmental impacts can result from dredge and fill projects, many of these impacts can be avoided and minimized. For those impacts that cannot be avoided, mitigation measures are available to offset those impacts. These conservation measures are discussed in Section 10.

Implementation of the conservation measures recommended within this report should create an ecologically sound shore protection project for Bogue Banks that avoids and minimizes damages to fish and wildlife resources. A dredge and fill project that utilizes ecologically compatible fill materials and avoids disturbing new seabeds would be the least environmentally damaging alternative and one we would support. Avoiding known fishing grounds and beach seining seasons would minimize damages to the local fishing industry, as would minimizing impacts to the prey base for those fishery resources. If these measures could be implemented, the Service would support a dredge and fill project on Bogue Banks.

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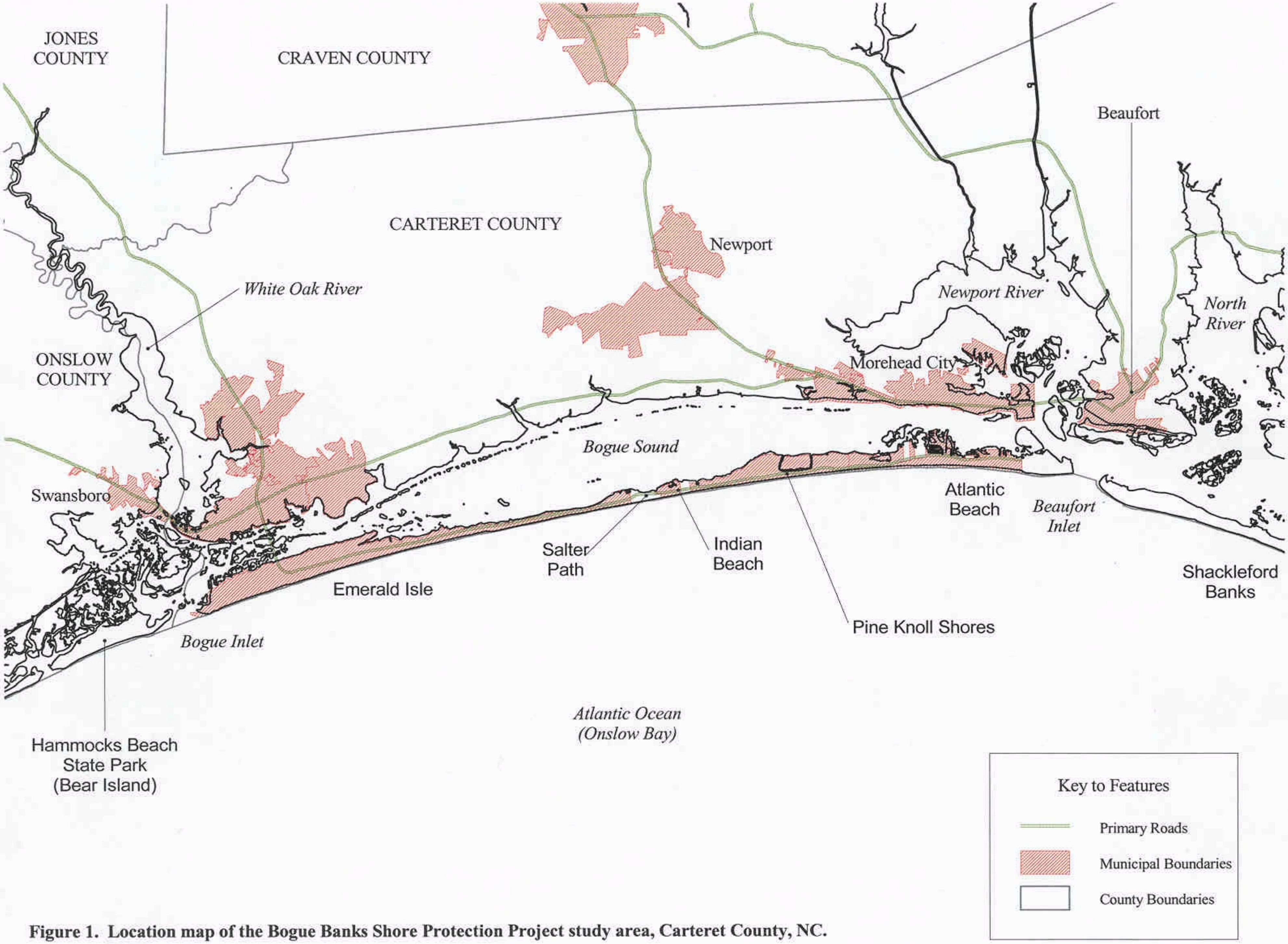


Figure 1. Location map of the Bogue Banks Shore Protection Project study area, Carteret County, NC.

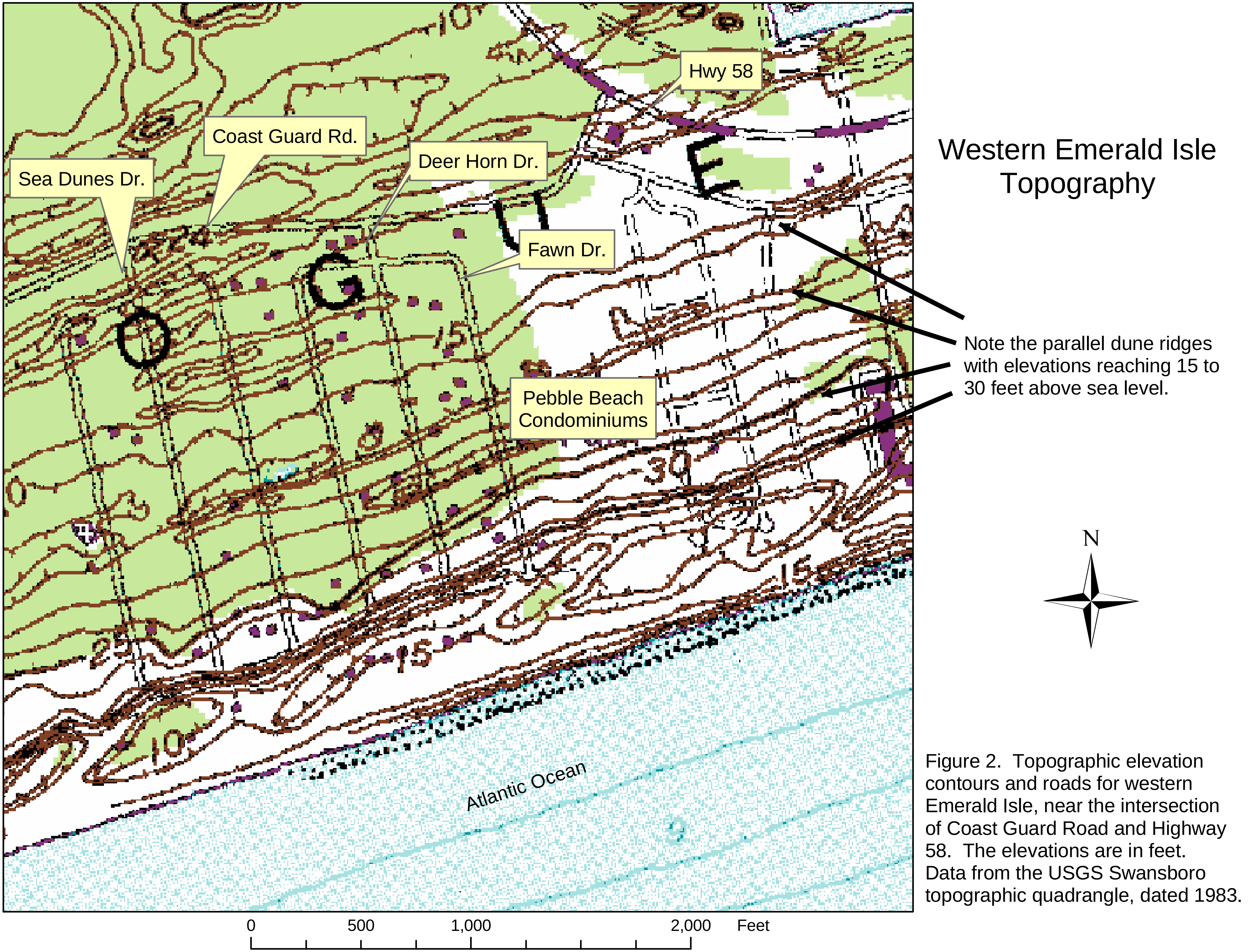


Figure 2. Topographic elevation contours and roads for western Emerald Isle, near the intersection of Coast Guard Road and Highway 58. The elevations are in feet. Data from the USGS Swansboro topographic quadrangle, dated 1983.

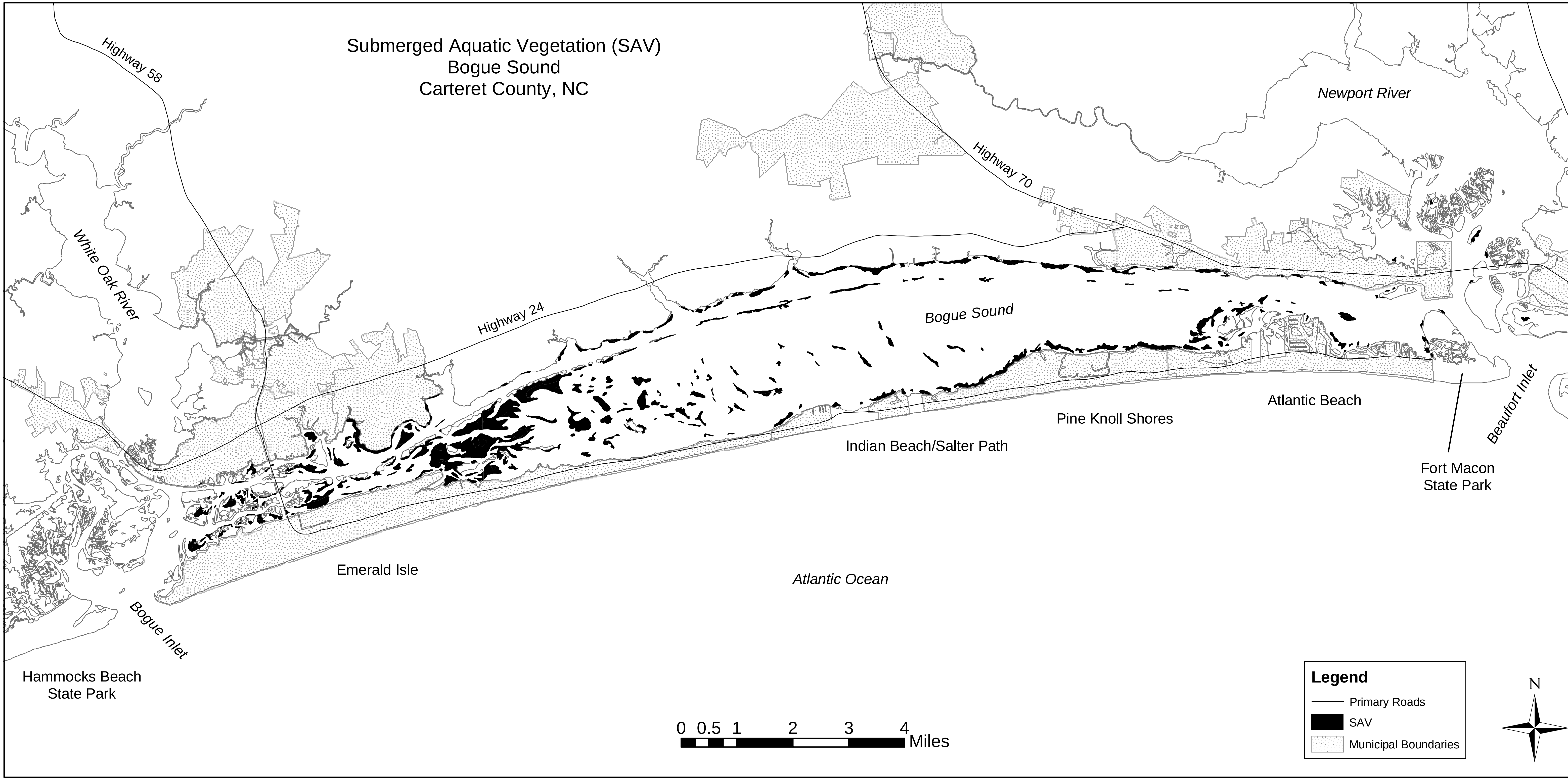


Figure 16. Submerged aquatic vegetation (SAV) in Bogue Sound. Data provided by NOAA and drafted using ESRI, Inc.'s ArcMap software with municipal boundaries and primary roads data layers from NC Department of Transportation and shoreline position data layer from the North Carolina Center for Geographic Information and Analaysis (CGIA).

SECTION 1. INTRODUCTION

Authority

This report is provided under authority of Section 2(b) of the Fish and Wildlife Coordination Act (FWCA) of 1958 (48 Stat. 401, as amended; 16 U.S.C. 661-667d). The FWCA essentially established fish and wildlife conservation as a coequal purpose or objective of federally funded or permitted water resources development projects.

The Bogue Banks Shore Protection Feasibility Study was authorized by a U.S. House of Representatives Committee on Transportation and Infrastructure resolution (Docket 2578) on July 23, 1998, which stated:

> "*Resolved by the Committee on Transportation of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers dated November 27, 1984, on Bogue Banks and Bogue Inlet, North Carolina, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of shore protection and related purposes and for Bogue Banks, North Carolina*."

In order to fully incorporate the conservation of fish and wildlife resources in the planning of water resources development, the FWCA mandates that federal agencies consult with the U. S. Fish and Wildlife Service (Service) and the state agency with the responsibility for fish and wildlife resources in the project area. The state agency with this responsibility is the North Carolina Wildlife Resources Commission (NC WRC).

Consultation during project planning is intended to allow state and federal resource agencies to determine the potential adverse impacts on fish and wildlife resources and develop recommendations to avoid, minimize, and/or compensate for detrimental impacts. Therefore, this report will:

1. Describe the fish and wildlife resources at risk in the project area;

2. Evaluate the potential adverse impacts, both direct and indirect, on these resources;

3. Develop recommendations to avoid, minimize, or compensate for any unavoidable, adverse environmental impacts; and,

4. Present an overall summary of findings and the position of the Service on the project.

This draft report will be submitted to the NC WRC for their review and comments. The report, when finalized, will include a letter of concurrence from the NC WRC and will constitute the formal report of the Service under Section 2(b) of the FWCA.

Subject of This Report

The Wilmington District, U. S. Army Corps of Engineers (Corps) has contacted the Service regarding a potential shore protection project along ~24 miles of oceanfront shoreline of Bogue Banks in Carteret County, North Carolina. The Bogue Banks Shore Protection Feasibility Study is being carried out under the U.S. Army Corps of Engineers' (Corps) General Investigation Program. In November 2001 the Wilmington District of the Corps initiated coordination with the Service for the Bogue Banks Shore Protection Project.

This report focuses on soft shoreline stabilization methods utilizing a large-scale dredge and fill project. Hard stabilization alternatives (i.e., groins, jetties, seawalls, offshore breakwaters) are not reviewed in this report due to the North Carolina prohibition on hard structures on ocean beaches. If the National Economic Development (NED) Plan contains a hard stabilization alternative, this report will require revision and supplemental sections.

Acronyms used in this report will be defined when first used. A list of all acronyms used is given in Appendix A.

Scope

The geographic scope of this report includes all areas that would be directly or indirectly impacted by the proposed project. The project area includes Bogue Sound, Bogue Inlet, Beaufort Inlet, Bogue Banks, and the marine areas up to 5 miles seaward of Bogue and Shackleford Banks.

The project area includes not only the beaches seaward of the communities requiring storm damage protection, but those areas into which sand could be transported by natural forces, the offshore and estuarine areas which are the most likely sand sources, and all areas likely to be impacted by the secondary development resulting from storm damage reduction measures. The project area also includes uplands that could be used to relocate structures away from the most vulnerable oceanfront area.

The temporal scope of this report extends from direct, immediate impacts of potential storm damage reduction measures to long-term, indirect impacts that may occur as a result of these measures. The report also considers the cumulative impacts of shoreline stabilization alternatives.

Prior Studies and Reports

The Service issued a Planning Aid Report (PAR) for the Bogue Banks Shore Protection Project on February 14, 2002. The PAR will be referenced as:

U.S. Fish and Wildlife Service (USFWS). 2002a. *Planning Aid Report on the Bogue Banks Shore Protection Project, Carteret County, North Carolina*. Raleigh, NC: USFWS Raleigh Ecological Services Field Office. 58 p.

The Corps has conducted other studies in the project area. A Section 933 report is currently under development regarding the possible expansion of the dredge disposal of maintenance material from the Morehead City navigational channel(s) from Atlantic Beach into Pine Knoll Shores. In June 2001 the Wilmington District issued a Section 111 Study on the dredging of the Morehead City Harbor and its potential effects on shoreline erosion at Pine Knoll Shores. The Section 111 study will be referenced as:

U.S. Army Corps of Engineers (USACE). 2001. *Summary of Morehead City Harbor Section 111 Study and Status Report on Other Projects Related to Beach Erosion at Bogue Banks*. Wilmington, NC: USACE Wilmington District. 199 p.

A locally-sponsored beach fill project was initiated in November 2001 under Corps Regulatory Permit No. 200000362. Phase I of this project placed beach fill along ~6 miles of oceanfront beach in Pine Knoll Shores, Indian Beach and Salter Path. The material was removed from three dredge sites located on the nearshore seafloor immediately south of Pine Knoll Shores, Indian Beach and Emerald Isle. The Environmental Impact Statement (EIS) prepared for the state regulatory permit for this project summarizes project features and fish and wildlife resources in the project area. These reports will be referenced as:

Coastal Science & Engineering, LLC (CSE) and Stroud Engineering PA. 2000. *Bogue Banks Beach Restoration Plan, Environmental Impact Statement, Draft #2*. Columbia, SC. Various paginations.

Coastal Science & Engineering, LLC (CSE). 2001. *Final Environmental Impact Statement [for the] Bogue Banks Beach Restoration Plan*. Coastal Science & Engineering. P.O. Box 8056 Columbia, South Carolina 27611-7687. Various paginations.

SECTION 2. STUDY AREA DESCRIPTION

The Bogue Banks Shore Protection Project study area encompasses several types of coastal ecosystems, which have been incorporated into this report as Bogue Banks Interior, Bogue Banks Oceanfront Shoreline, Bogue Banks Estuarine Shoreline, Bogue Sound, Bogue Inlet, Beaufort Inlet, and Offshore Marine. The study area is in Carteret and Onslow Counties, North Carolina, south of Cape Lookout. Bogue Banks is an approximately 24 mile long barrier island with a relatively unique east-west orientation. Beaufort Inlet borders the island to the east and separates Bogue Banks from Shackleford Banks. Bogue Inlet borders Bogue Banks to the west and separates the island from Bear Island. Shackleford Banks is part of the Cape Lookout National Seashore, and Bear Island is part of the Hammocks Beach State Park; therefore Bogue Banks is a developed barrier island between two undeveloped, preserved islands. Bogue Sound separates Bogue Banks from the mainland and Onslow Bay (Atlantic Ocean) faces south. The study area includes Bogue Banks, Bogue Sound, Beaufort and Bogue Inlets, and the seafloor out to 5 miles seaward of Shackleford and Bogue Banks. Figure 1 shows the location of the project area and its surrounding landscape.

The natural history of Bogue Banks has been described in Pilkey et al. (1975), Stanczuk (1975), Steele (1980), Mallette (1986), Flint (1988), Moslow and Heron (1994) and Pilkey et al. (1998). The barrier island is one of the most studied in North Carolina due to its proximity to the Duke University Marine Lab, the Institute of Marine Sciences at the University of North Carolina, Chapel Hill, and federal laboratories of the National Oceanic and Atmospheric Administration (NOAA). Section 5 of this report summarizes the more salient features of the natural history of the study area. Appendix B lists the federally-threatened and endangered species for Onslow and Carteret Counties, North Carolina.

Biological Communities

The Service has described the various coastal biological communities previously in other FWCA reports: USFWS (1999) and USFWS (2001) for the Dare County Beaches (Bodie Island Portion) Hurricane Protection and Beach Erosion Control, Dare County, North Carolina; USFWS (2000a) for the Brunswick County Beaches (Oak Island and Holden Beach Portions) Project; USFWS (2000b) for the Wilmington Harbor, North Carolina, 96 Act; and USFWS (2002a) for this project. The Planning Aid Report (PAR) for the Bogue Banks Shore Protection Project (USFWS 2002a) and the Draft Fish and Wildlife Coordination Act Report (DFWCAR) for the Brunswick Beaches Storm Damage Reduction Project (USFWS 2000a) summarized the characteristics of barrier island communities for southern North Carolina and are incorporated by reference into this report. Specific biological information is contained in Section 5 of this report.

Figure 1 insert

SECTION 3. FISH AND WILDLIFE CONCERNS AND PLANNING OBJECTIVES

The involvement of the Service in this planning process is in response to a Congressional mandate through the FWCA which directs that the conservation of fish and wildlife resources shall receive full and equal consideration and be coordinated with other features of federal projects. Fish, wildlife, and their habitats are valuable public resources which are conserved and managed for the people by state and federal governments. If proposed land or water developments may reduce or eliminate the public benefits that are provided by such natural resources, then state and federal resources agencies have a responsibility to recommend means and measures to mitigate such losses. In the interest of serving the public, it is the policy of the Service to seek to mitigate losses of fish, wildlife, and their habitats and to provide information and recommendations that fully support the Nation's needs for fish and wildlife resource conservation as well as sound economic and social development through balanced, multiple use of the Nation's natural resources.

Shore protection projects that aim to reduce storm damages may impact a variety of fish and wildlife resources and their habitats. These impacts can be direct and immediate, indirect and continuing after project completion, and long-term or permanent. The Service has summarized concerns regarding general and specific impacts potentially resulting from large-scale shoreline stabilization and storm damage reduction projects in USFWS (1999), USFWS (2000a), USFWS (2000b), USFWS (2001) and USFWS (2002a). These reports are hereby incorporated by reference.

Potential Positive Consequences of the Project

In addition to the potential environmental impacts associated with a shore protection project, there may be opportunities for fish and wildlife resource conservation and enhancement. Benefits to fish and wildlife include the creation of sea turtle and shorebird nesting habitat and possibly the creation of reef habitat as sand is removed from hard bottoms offshore. Specific recommendations to create, restore or enhance fish and wildlife resources are outlined in the sections of this report on Conservation Measures.

Planning Objectives

Careful planning and a conscientious balancing of economic considerations with environmental concerns can produce a project with minimal, short- and long-term environmental impacts. The Service’s Mitigation Policy (January 23, 1981, Federal Register v. 46, n. 15, pp. 7644-7663) allows for the Service to support a proposed project if the following criteria are met:

1) The project is ecologically sound;
2) The least environmentally damaging alternative is selected;
3) Every reasonable effort has been made to avoid or minimize damage or loss of fish and wildlife resources and uses;

4) All important recommended means and measures have been adopted with guaranteed implementation to satisfactorily compensate for unavoidable damage or loss consistent with the appropriate mitigation goal; and
5) For wetlands and shallow water habitats, the proposed activity is clearly water dependent and there is a demonstrated public need.

The Service uses these five criteria as planning objectives in this report and will support a project if it meets these five criteria. In accordance with the FWCA, as amended, these planning objectives allow the Service to formulate recommendations that give full and equal consideration to fish and wildlife resources with the economic benefits expected from the project.

SECTION 4. EVALUATION METHODS

Descriptions of natural resources present within the study area and the preliminary assessment of the environmental impacts of the proposed project are based on previous studies for similar projects, published literature, and personal communications with knowledgeable individuals. Published reports and studies were examined to determine their relevance to the proposed project. Material which described potential environmental impacts of similar projects and methods of reducing these impacts are incorporated by reference in this report.

Several field site investigations have been conducted by the Service in the project area. Field visits include surveys following Hurricanes Bertha (1996), Fran (1996), Bonnie (1998), Dennis (1999) and Floyd (1999). Numerous field site investigations have been conducted in relation to Corps Regulatory permits throughout the project area. Other field surveys and data collection were conducted more recently in June 2000, April 2001, May 2001, June 2001, September 2001, February 2002, March 2002, May 2002, June 2002, and August 2002. Investigations were documented with photographs, field notes, measurements and physical samples. These records are available in the Raleigh Ecological Services Field Office.

Additional analyses were conducted using remote sensing data and Geographic Information Systems (GIS), primarily using ArcView 3.2a software. GIS data from the U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), North Carolina Center for Geographic Information and Analysis (CGIA), the Service and various internet resources were used to compile landscape level analyses of habitats in the project area. These analyses were then ground-truthed during field surveys. Data were also gathered from the North Carolina Wildlife Resources Commission (NC WRC) and Division of Marine Fisheries (NC DMF) regarding specific biological resources in the project area. These data are presented in tables, figures and technical appendices throughout this report and are available upon request except where it is proprietary by the NC DMF.

Nomenclature in this report follows Tiner (1993) and Duncan and Duncan (1987) for coastal plants; Robins and Ray (1986) for fish; Martof et al. (1980) for amphibians and reptiles; Sibley (2000) for birds; Webster et al. (1985) for mammals; Turgeon et al. (1988) for mollusks; Ruppert and Fox (1988) for invertebrates; and Williams et al. (1989) for decapod crustaceans.

Both common and scientific names from cited literature follow the original publication. If the Service is aware of a widely accepted synonym for the common name, that synonym is given in brackets. If the Service is aware of a change in the scientific name of a given species, the revised nomenclature is included in brackets following the published name.

Resource category determinations were prepared for all habitat types in the project area as per the Service's Mitigation Policy (January 23, 1981, Federal Register v. 46, n. 15, pp. 7644-7663). All of the data sources listed above were incorporated into the resource category determinations. The determinations were coordinated with the NC WRC, NC DMF, National Marine Fisheries Service (NMFS) and the Corps. Where data are limited or not available, best professional judgement erring on the conservation of the resource(s) was also used. These limitations are clearly noted in this report. The resource category determination approach allows an objective evaluation of the functions and values of each habitat, utilizing data on the status and trends of the evaluation species both regionally and nationally. Some habitats may be harmed or enhanced by the proposed shore protection project, and the individual habitat values allow unique and high value areas to be identified prior to any action.

The four resource categories, ranked 1 to 4 with 1 being the most valuable, are described below. The conservation measures and recommendations in Sections 9, 10 and 11 follow the mitigation goals associated with each resource category, as defined in the Service's Mitigation Policy (Federal Register v. 46, n. 15, pp. 7644-7663).

Resource Category 1

Resource Category 1 habitats have high value for evaluation species and are unique and irreplaceable on a national basis or in the ecoregion section. These habitats include areas with high biodiversity, an unusual assemblage of species, high species endemism, or are pristine, rare or relict habitats. Resource Category 1 determinations will emphasize wetland and coastal areas but do not include transitory habitats and geologic features without endemic species. The mitigation goal for Resource Category 1 habitats is no loss of existing habitat value. Resource Category 1 habitats must be designated by the Regional Director.

Resource Category 2

Resource Category 2 habitats have high value for evaluation species and are relatively scarce or becoming scarce on a national basis or in the ecoregion. The mitigation goal for these habitats is no net loss of in-kind habitat value.

Resource Category 3

Resource Category 3 habitats have high to medium value for evaluation species and are relatively abundant on a national basis. The mitigation goal for Resource Category 3 habitats is no net loss of habitat value while minimizing loss of in-kind habitat value.

Resource Category 4

Resource Category 4 habitats have medium to low value for evaluation species and a mitigation goal of minimizing loss of habitat value.

In addition to the Service's guidance on resource values and mitigation, the Corps Planning Guidance provides for an incremental analysis and mitigation for project impacts that are determined to be significant (ER 1105-2-100). Significance is "derived from institutional, public or technical recognition. Institutional recognition of a resource or effect means its importance is recognized and acknowledged in the laws, plans and policies of government and private groups.

Technical recognition ... is based upon scientific or other technical criteria that establishes its significance. Public recognition means some segment of the general public considers the resource or effect to be important ... [and] may manifest itself in controversy, support or opposition expressed in any number of formal or informal ways" (ER 1105-2-100, p. 2-13). The Endangered Species Act, Marine Mammals Protection Act, Migratory Bird Treaty Act, Magnuson-Stevens Fishery Conservation and Management Act, the Colonial Waterbird Conservation Plan, U.S. Shorebird Conservation Plan and Executive Orders 13186 and 11990 constitute institutional recognition. The request by various non-governmental organizations for a cumulative impacts analysis and/or Programmatic Environmental Impact Statement for coastal projects in North Carolina constitutes public recognition of the significance of the coastal ecosystem.

Therefore the following fish and wildlife resources are considered significant and are utilized as evaluation species for this report. Federally threatened or endangered species are not considered evaluation species for the purpose of assessing the resource categories of a project area. An assessment of the significance of each potential impact (positive or negative) to these species and their habitats is provided throughout Sections 8 and 9. This report divides the project area into the following ecological sections: Bogue Sound, Bogue Inlet, Beaufort Inlet, Estuarine shoreline (of Bogue Banks), Oceanfront shoreline (of Bogue Banks), Bogue Banks interior, Nearshore marine (less than 30 feet water depth) and Offshore marine (greater than 30 feet water depth).

Table 1. Evaluation species for this report and their occurrence in the project area.

Species	Community	Occurrence in Project Area
King mackerel *Scomberomorus cavalla*	Migratory pelagic fish	Nearshore and offshore marine
Spanish mackerel *Scomberomorus maculatus*	Migratory pelagic fish	Nearshore and offshore marine
Bluefish *Pomatomus saltatrix*	Migratory pelagic fish	Nearshore and offshore marine
Gag *Mycteroperca microlepis*	Migratory demersal fish from snapper-grouper complex	Nearshore and offshore marine
Gulf kingfish *Menticirrhus littoralis*	Migratory surf zone (demersal) fish	Oceanfront shoreline and nearshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Florida pompano *Trachinotus carolinus*	Migratory surf zone (demersal) fish	Oceanfront shoreline and nearshore
Bottlenose dolphin *Tursiops truncatus*	Marine mammal	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound

Southern flounder *Paralichthys lethostigma*	Migratory demersal	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Spot *Leiostomus xanthurus*	Migratory demersal fish	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Red drum *Sciaenops ocellatus*	Resident demersal fish	Nearshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
American shad *Alosa sapidissima*	Anadromous fish	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
American eel *Anguilla rostrata*	Catadromous fish	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Atlantic menhaden *Brevoortia tyrannus*	Migratory pelagic fish	Nearshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Hogchoker *Trinectes maculatus*	Resident demersal fish	Bogue Sound
Striped mullet *Mugil cephalus*	Migratory demersal fish	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Atlantic croaker *Micropogonias undulatus*	Migratory demersal fish	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound
Horseshoe crab *Limulus polyphemus*	Migratory arthropod	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound; Estuarine shoreline
Blue crab *Callinectes sapidus*	Decapod crustacean	Bogue Inlet; Beaufort Inlet; Bogue Sound; Estuarine shoreline
Shrimp (brown, white and pink) *Penaeus* sp.	Migratory decapod crustacean	Nearshore and offshore marine; Bogue Inlet; Beaufort Inlet; Bogue Sound; Estuarine shoreline
Diamondback terrapin *Malaclemys terrapin*	Reptile	Bogue Sound; Estuarine shoreline
Sand dollar *Mellita quinquiesperforata*	Benthic echinoderm	Nearshore and offshore marine

Scolelpsis squamata	Benthic polychaete worm	Oceanfront and inlet shorelines; Nearshore and offshore marine
Moon snail *Polinices* sp.	Benthic gastropod	Nearshore and offshore marine; Bogue Sound
Star coral *Astrangia danae*	Encrusting epifauna	Nearshore and offshore marine
Quilling piddock *Jouanettia quillingi*	Rock-boring, endolithic bivalve mollusk	Nearshore and offshore marine
Coquina clam *Donax variabilis*	Benthic bivalve mollusk	Oceanfront shoreline; Bogue Inlet; Beaufort Inlet; Nearshore marine
Mole crab *Emerita talpoida*	Benthic arthropod crustacean	Oceanfront shoreline; Bogue Inlet; Beaufort Inlet; Nearshore marine
Ghost crab *Ocypode quadrata*	Burrowing arthropod	Oceanfront shoreline; Bogue Inlet; Beaufort Inlet
Eastern oyster *Crassostrea virginica*	Sessile bivalve mollusk	Bogue Sound
Hard clam (Northern quahog) *Mercenaria mercenaria*	Burrowing bivalve mollusk	Bogue Sound; Nearshore marine
Bay scallop *Argopecten irradians*	Bivalve mollusk	Bogue Sound
Marsh periwinkle *Littorina irrorata*	Gastropod	Bogue Sound; Estuarine shoreline
Cordgrass *Spartina* spp.	Marsh grass	Estuarine shoreline; Bogue Inlet; Beaufort Inlet; Bogue Sound
Eelgrass *Zostera marina*	Submerged aquatic vegetation	Bogue Inlet; Beaufort Inlet; Bogue Sound
Widgeon grass *Ruppia maritima*	Submerged aquatic vegetation	Bogue Inlet; Beaufort Inlet; Bogue Sound
Sargassum *Sargassum filipendula*	Marine algae	Oceanfront shoreline; Nearshore and offshore marine
Live oak *Quercus virginiana*	Evergreen canopy tree	Bogue Banks interior
Red bay *Persea palustris*	Evergreen wetland shrub	Bogue Banks interior; Estuarine shoreline

Atlantic white cedar *Chamaeocyparis thyoides*	Maritime wetland tree	Bogue Banks interior
Sea oats *Uniola paniculata*	Dune grass	Oceanfront shoreline
Boat-tailed grackle *Quiscalus major*	Migratory landbird	Bogue Banks interior; Estuarine shoreline
Eastern painted bunting *Passerina ciris ciris*	Migratory landbird	Bogue Banks interior; Bogue Sound; Estuarine shoreline
Marsh wren *Cistothorus palustris*	Migratory landbird	Bogue Sound; Estuarine shoreline; Bogue Banks interior
American oystercatcher *Haematopus palliatus*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Estuarine shoreline
Wilson's plover *Charadrius wilsonia*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound
Red knot *Calidris canutus*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Nearshore marine
Sanderling *Calidris alba*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline
Willet *Catoptrophorus semipalmatus*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline; Estuarine shoreline
Dunlin *Calidris alpina*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline; Estuarine shoreline
Short-billed dowitcher *Limnodromus griseus*	Migratory shorebird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline
Gull-billed tern *Sterna nilotica*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline; Estuarine shoreline
Common tern *Sterna hirundo*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline; Estuarine shoreline
Black skimmer *Rynchops niger*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline; Estuarine shoreline

Least tern *Sterna antillarum*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Oceanfront shoreline; Estuarine shoreline
Brown pelican *Pelecanus occidentalis*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Nearshore marine; Estuarine shoreline
Snowy egret *Egretta thula*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Estuarine shoreline
Little blue heron *Egretta caerulea*	Colonial waterbird	Bogue Inlet; Beaufort Inlet; Bogue Sound; Estuarine shoreline
Red phalarope *Phalaropus fulicarius*	Migratory shorebird	Nearshore and offshore marine
Cory's shearwater *Puffinus diomedea*	Migratory seabird	Nearshore and offshore marine
Northern gannet *Morus bassanus*	Migratory seabird	Nearshore marine
Black rail *Laterallus jamaicensis*	Migratory waterfowl	Bogue Sound; Estuarine shoreline
Common loon *Gavia immer*	Migratory waterfowl	Bogue Sound
Canvasback *Aythya valisineria*	Migratory waterfowl	Bogue Inlet; Beaufort Inlet; Bogue Sound
Red-breasted merganser *Mergus serrator*	Migratory waterfowl, sea duck	Bogue Inlet; Beaufort Inlet; Bogue Sound

Tables 2 through 5 summarize the ecological niche and the available population status information for each of the evaluation species used in the resource category determination process. Table 2 lists the fishery resources. Table 3 contains vegetation evaluation species. Table 4 describes the avian species. Table 5 itemizes the invertebrate species used in the evaluation.

Table 2. Aquatic evaluation species in the Bogue Banks Shore Protection Project study area utilized in this report for the assessment of resource category determinations.

Species	Ecological Niche	Population Status†	Management∮
King mackerel *Scomberomorus cavalla*	Migratory, pelagic Live 22-26 yrs Found offshore, nearshore, inlets, and uncommonly in estuaries and rivers Present offshore year-round, nearshore April to November	Viable	SAFMC, NMFS, NC DMF
Spanish mackerel *Scombermorus maculatus*	Migratory, pelagic Short-lived (5-8 yrs) Present from early April to November Spawn May to September Found offshore, nearshore, inlets, and estuaries (juveniles)	Viable	ASMFC, SAFMC, NMFS, NC DMF
Bluefish *Pomatomus saltatrix*	Migratory, pelagic, schooling Live 12-14 yrs Present year-round due to location between two populations Overwinter in project area High position in food web: adults are visual, piscivorous predators; juveniles feed on plankton and invertebrates Nearshore and estuarine nursery areas	Recovering	ASMFC, MAFMC, NMFS, NC DMF
Gag *Mycteroperca microlepis*	Migratory, demersal Live to 22 yrs Reef/hardbottom feeder Estuarine-dependent nursery in SAV or oyster reefs Juveniles emigrate in fall to nearshore reefs/hardbottoms	Viable	SAFMC, NMFS, NC DMF
Gulf kingfish *Menticirrhus littoralis*	Migratory Short-lived (6-9 yrs) Spawn April to August Estuarine and surf-zone dependent nursery areas	Unknown	NC DMF
Florida pompano *Trachinotus carolinus*	Migratory Surf zone feeding and nursery areas		

Bottlenose dolphin *Tursiops truncatus*	Marine mammal Long-lived (40-50 yrs) Likely present year-round Live-births in spring and summer High position in food web Found in estuaries, inlets and nearshore (separate offshore and near-shore population)	Depleted	NMFS
Southern flounder *Paralichthys lethostigma*	Migratory, groundfish Short-lived (6-8 yrs) Spawn nearshore November to March Estuarine nursery areas (prefer muddy bottoms, low salinity) Adults usually return to estuaries post-spawning Found in estuaries, inlets and nearshore	Overfished, population is down 32% in last decade	NC DMF
Spot *Leiostomus xanthurus*	Migratory, benthic-feeding, schooling Short-lived (5 yrs) Spawn offshore (75-90 km) in late fall to early spring, peak December to January Pelagic larvae and post-larvae drift to estuaries, likely peak February to March Congregate along beaches before offshore spawning migration Middle position in food web: larvae feed on plankton, juveniles and adults feed on benthic infauna and epifauna (partly olfactory predators) Estuarine nursery areas in SAV, marshes and tidal creeks Found in estuaries, inlets, nearshore and offshore Sensitive to temperature and salinity changes, pipe intakes One of most abundant species in project area	Viable	ASMFC, NC DMF
Atlantic croaker *Micropogonias undulatus*	Migratory Spawn offshore fall through spring Larvae drift through inlets to estuaries Estuarine nursery areas Found in rivers, estuaries, inlets, nearshore and offshore areas One of most abundant species caught in survey trawls of project area	Concern	ASMFC, NC DMF

Red drum *Sciaenops ocellatus*	Migratory, North Carolina state saltwater fish Long-lived (up to 62 yrs) Present year-round Spawn in Pamlico Sound and at inlets and beaches in late summer to early fall Middle position in food web: feed on zooplankton, invertebrates and small fish Estuarine larvae (grassy or muddy bottoms) and juveniles (marshes) Congregate in surf zone during spring and fall Found in estuaries, inlets and nearshore areas	Overfished	ASMFC, SAFMC, NMFS, NC DMF
Atlantic menhaden *Brevoortia tyrannus*	Migratory, schooling Short-lived (8-10 yrs) Present year-round; as larvae: January - March; juveniles: April - December, and adults: May - December (estuarine) and year-round (oceanic) Spawn offshore during fall and winter in NC, peaking from December to February, concentrating from north of Cape Hatteras to south of Cape Lookout; spawn in ocean during spring and early summer north to Long Island Near bottom of food web as adults: filter feed phytoplankton and detritus, are fed upon by many larger fish Estuarine nursery areas, especially marshes and small creeks; occur well upstream in coastal rivers Found in estuaries, inlets, nearshore and offshore areas Commercially valuable for fishmeal (used for animal feed), fish oil (used as an industrial and food base), and bait	Viable	ASMFC, NMFS, NC DMF
American shad *Alosa sapidissima*	Migratory, anadromous Short-lived (4-10 yrs) Spawn from March to mid-June Typically die after spawning once Middle position in food web: feed dominantly on plankton and insects, are fed upon by American eel, striped bass, porpoises, kingfish, tuna and birds Freshwater-dependent for spawning Found in rivers, estuaries, inlets, nearshore and offshore areas	Concern	ASMFC, NC DMF

American eel *Anguilla rostrata*	Migratory, catadromous Long-lived (up to 85 yrs) Spawn from winter to early spring offshore in Sargasso Sea Typically die after spawning once Middle position in food web: feed on invertebrates, small fish Utilize many aquatic habitats for different life stages, preferring soft bottoms with vegetation Found in rivers, estuaries, inlets, nearshore and offshore areas	Unknown	ASMFC, NC DMF
Hogchoker *Trinectes maculatus*	Demersal Present on mud, silt or sand bottoms of estuaries Spawns from late spring to summer Young may move upstream in freshwater rivers over 100 miles Low position in food web, feeding mostly on worms and small crustaceans Not economically important Found in estuaries and rivers		
Striped mullet *Mugil cephalus*	Migratory Short-lived (< 11 yrs) Spawn from September to January, peaking October through early December Spawn near inlets, nearshore or offshore in groups High fecundity Middle position in food web: feed on microorganisms, algae and decaying plant material, are fed upon by birds, fish, dolphin and sharks Found in rivers, estuaries, inlets, nearshore and offshore areas	Concern	NC DMF
Horseshoe crab *Limulus polyphemus*	Migratory, arthropod Bottom-feeder and source of bioturbation Lay eggs on sandy estuarine beaches Eggs very important food source for migratory shorebirds Medically valuable species for its blood Found in estuaries, inlets, nearshore and offshore areas		ASMFC, NC DMF

Blue crab *Callinectes sapidus*	Decapod crustacean Short-lived (2-3 yrs) Present year-round Spawns at inlets during the summer, larvae are pelagic Middle position in food web: is an omnivore scavenger and detrivorous, is fed upon by birds and fish Estuarine nursery areas in SAV and marshes Found in inlets and estuaries Utilize many microhabitats for different life stages and seasons	Concern	NC DMF
Shrimp *Penaeus* spp. (Three economically important species: brown, pink and white shrimp)	Migratory, decapod crustacean Short-lived (< 1.5 yrs) Present year-round Spawn nearshore and offshore throughout the year (different species at different seasons) Post-larvae drift into estuaries, adults are burrowers Low position in food web: benthic omnivores of organic matter microalgae, and small invertebrates, are prey for birds and fish Estuarine nursery areas, preferring marsh, SAV and tidal creeks Found in estuaries, inlets, nearshore and offshore areas Sensitive to dredge material and hard stabilization of shorelines	Viable	SAFMC, NMFS, NC DMF
Diamondback terrapin *Malaclemys terrapin*	Reptile Present year-round Nests May through July on sandy beaches, dunes and islands Forage on mollusks, worms, crabs, dead fish and marsh plants Found in estuaries, especially salt marshes	Rare or uncommon in NC; State and Federal Species of Concern	NC WRC

[†] The most recent population or stock status as designated by the relevant management authority.
[∮] Management authority acronyms: ASMFC - Atlantic States Marine Fishery Commission; MAFMC - Mid-Atlantic Fishery Management Council; NC DMF - North Carolina Division of Marine Fisheries; NC WRC - North Carolina Wildlife Resources Commission; NMFS - National Marine Fisheries Service; SAFMC - South Atlantic Fishery Management Council.

Data sources: ASMFC (www.asmfc.org), E-nature (www.enature.com), Facey and Van Den Avyle (1986), Hales and Van Den Avyle (1989), Larson et al. (1989), LeGrand and Hall (1999), Meyer (1994), Muncy (1984), NC DMF (www.ncfisheries.net), NMFS (www.nmfs.noaa.gov), Oliver et al. (1989), Rogers and Van Den Avyle (1983), Rogers and Van Den Avyle (1989), Van Den Avyle and Fowler (1984), VIMS (www.fisheries.vims.edu/femap/), and Wilson (1995).

Table 3. Vegetation evaluation species in the Bogue Banks Shore Protection Project study area utilized in this report for the assessment of resource category determinations.

Species	Ecological Niche	Distribution Status	Abundance Status	Management[∮]
Cordgrass *Spartina* spp.	Saltwater or brackish marsh	Regional (southeast) Locally fragmented by shoreline stabilization on individual properties	Declining Loss of 60,000 acres regionally 1970s to 80s[1]	USACE
Eelgrass *Zostera marina*	Submerged aquatic vegetation (SAV), freshwater to saltwater, densest in spring	Temperate, cold water species; NC is southern most distribution	Unknown, possibly stable or declining	NMFS, NC DMF, NC Coastal Resources Commission
Widgeon grass *Ruppia maritima*	SAV, food for migratory waterfowl, freshwater to saltwater, densest in summer	Temperate species	Unknown, possibly stable or declining	NMFS, NC DMF, NC Coastal Resources Commission
Sargassum *Sargassum filipendula*	Marine algal meadows on hardbottoms, also free-floating when ripped from moorings; nursery and juvenile habitat for fish and sea turtles	Unknown	Unknown	SAFMC, NMFS
Live oak *Quercus virginiana*	Maritime forest; evergreen canopy hardwood	Very limited in NC [2]	Declining due to lot clearing for development	Local
Red bay *Persea palustris*	Maritime scrub-shrub wetlands	Wetland type is very rare to extremely rare in NC [2]	Declining habitat, down 3.1 million acres regionally[1]; NC leads region in palustrine forest wetland loss	

Atlantic white cedar *Chamaeocyparis thyoides*	Maritime swamp forest	Thought to be less than 5% of historical distribution	Declining	USACE, NC DCM
Sea oats *Uniola paniculata*	Dune colonizer and builder	Cape Henry, VA, to Texas	Common[3] Native species that is being replaced by American beachgrass in landscaped dune plantings	

[1] Trends as cited in Hefner et al. (1994)
[2] Distribution as cited in Shafale and Weakley (1990)
[3] Abundance as cited in Duncan and Duncan (1987)

Data sources: Duncan and Duncan (1987), Fonseca et al. (1998), Hefner et al. (1994), Graetz (1994), Meyer (1994), Riggs et al. (1998), and Shafele and Weakley (1990).

Table 4. Avian evaluation species in the Bogue Banks Shore Protection Project study area utilized in this report for the assessment of resource category determinations.

Species	Ecological Niche	National Population Status	Regional or State Population Status
Boat-tailed grackle *Quiscalus major*	Migratory landbird Present year-round Colonial nester Ground gleaner and hawker omnivore Found in coastal marshes and adjacent open habitats		
Eastern painted bunting *Passerina ciris ciris*	Migratory landbird Nests in trees and shrubs Ground and foliage gleaner Found in terrestrial vegetation habitats Males are highly territorial	Federal Species of Concern	Significantly Rare[3]
Marsh wren *Cistothorus palustris*	Migratory landbird Present year-round Nests in marsh grasses, a polygynous breeder Ground and foliage gleaner, hawker Found in fresh and brackish marsh habitats Destroys competitive nests of marsh-nesting blackbirds		
American oystercatcher *Haematopus palliatus*	Migratory shorebird Present year-round Nests on bare ground Aquatic gleaners/sweepers and probers/priers Found in estuaries, inlets, beachfront habitats Project area has notable concentration of wintering population Long parental care period (up to 1 yr) to teach young foraging techniques	Species of High Concern[1]	Extremely High Priority[4] Region extremely important for breeding, very important to species for wintering[4]

Wilson's plover *Charadrius wilsonia*	Migratory shorebird Present during spring, summer and fall Nests on sand beaches and tidal mud flats Loosely colonial with terns and oystercatchers Terrestrial and aquatic gleaners, a visual predator Found in estuaries, inlets and beachfront habitats	Species of High Concern[1]	Significantly rare[3] High Priority[4] Region extremely important to species for breeding[4]
Red knot *Calidris canutus*	Migratory shorebird Present during spring and fall migrations, sporadic in winter Aquatic and terrestrial prober/gleaners Found in estuaries, inlets and beachfront habitats Forage in large flocks during winter Have large territories	Species of High Concern[1] (known to be in decline)	Extremely High Priority[4]
Sanderling *Calidris alba*	Migratory shorebird High concentration of wintering population Aquatic and terrestrial prober/gleaners Found in inlet and beachfront habitats Strong fidelity to wintering grounds, defends foraging territory	Species of High Concern[1] (known to be in decline)	Moderate Priority[4]
Willet *Catoptrophorus semipalmatus*	Migratory shorebird Present year-round Nests on bare ground Aquatic gleaner, visual predator, wader Found in salt marshes, tidal mud or sand flats Strong fidelity to foraging territory, defend winter territories	Species of Moderate Concern[1]	Moderate Priority[4]
Dunlin *Calidris alpina*	Migratory shorebird Present during winter Aquatic and terrestrial prober/gleaners Found in beachfront, inlet and estuarine habitats Has large territories, breeding site fidelity Wintering populations may have sex separation with males concentrated more to the north of the wintering range	Species of Moderate Concern[1] (known to be in decline)	Moderate Priority[4]

Short-billed dowitcher *Limnodromus griseus*	Migratory shorebird High concentration during winter Aquatic and terrestrial prober/gleaner, wader Found in estuarine, inlet, and beachfront habitats Forage in large flocks with sandpipers and plovers during winter	Species of High Concern[1] (known to be in decline)	High Priority[4]
Gull-billed tern *Sterna nilotica*	Colonial waterbird Present spring, summer and fall Nests on bare ground in colonies with other terns and black skimmers Forages by hovering and pouncing on prey Found in salt marshes, inlets and estuarine habitats	Species of Low Concern[2]	State Threatened
Common tern *Sterna hirundo*	Colonial waterbird Present spring, summer and fall Nests on bare ground in colonies with other terns and black skimmers Courtship feeding ritual Forages by high-diving for fish Defend foraging territories during breeding season Found in estuaries, inlets, beachfront, and nearshore habitats	Species of Moderate Concern[2] (apparent stable population)	Significantly Rare[3]
Least tern *Sterna antillarum*	Colonial waterbird Present spring, summer and fall Nests on bare ground and rooftops in colonies with other terns and black skimmers Courtship feeding ritual Forages by plunge diving for prey Found in freshwater, marine, and estuarine waters, oceanfront beaches, sand flats and open dunes Nesting vulnerable to depradation	Species of High Concern[2] (apparent population decline)	Significantly Rare[3] Species of Concern[3]
Brown pelican *Pelecanus occidentalis*	Colonial waterbird Present year-round Nests in trees, shrubs or on the ground Forages by high-diving for fish Found in estuaries, inlets and nearshore habitats Long-lived (25-30 yrs)	Species of Moderate Concern[2] (apparently stable population) Remains listed on Gulf Coast	Species of Concern[3] Removed from Endangered Species list in 1985

Black skimmer *Rynchops niger*	Colonial waterbird Present year-round Nests on bare ground in colonies with terns Forages by skimming water for prey (tactile hunter) Found in estuaries, inlets and beachfront habitats Sensitive to any human disturbance of colony Roosts in flocks on sandbars, shoals and beaches	Species of High Concern[2] (apparently population decline)	Species of Concern[3]
Snowy egret *Egretta thula*	Colonial wading bird Present year-round Nests in colonies in shrubs and deciduous trees Diverse foraging techniques for aquatic and terrestrial fauna, usually wading with active pursuit of prey (stalk and strike) Found in estuaries and inlet habitats Communal roosts at night	Species of High Concern[2] (apparent population decline)	Species of Concern[3]
Little blue heron *Egretta caerulea*	Colonial wading bird May be present year-round Nests in colonies in shrubs and deciduous trees; Diverse foraging techniques, usually stalk and strike prey Found in estuaries and inland habitats	Species of High Concern[2] (apparent population decline)	Species of Concern[3]
Red phalarope *Phalaropus fulicarius*	Migratory shorebird Present during spring and fall migrations, sporadic in winter Aquatic gleaner for marine invertebrates, larvae, plankton Found in nearshore and offshore marine habitats	Species of Moderate Concern[1] (thought to be in decline)	Species of High Concentration[4]
Cory's shearwater *Puffinus diomedea*	Migratory seabird Regionally high concentration in NC waters Present April to late November, peak mid-July to early August Forages by skimming, scavenging and diving for fish, squid, crustaceans, seaweed, and refuse May flock in rafts in nearshore and offshore areas Usually flies just above ocean surface	Species of Moderate to Low Concern[2] (apparently stable population)	

Northern gannet *Morus bassanus*	Migratory seabird Present during spring and fall migrations and winter Forages by high diving (often from > 90 ft) for fish and squid Found in nearshore areas, often visible from shore	Species Not at Risk[2] (biologically significant population increase)	
Black rail *Laterallus jamaicensis*	Migratory waterfowl Present year-round Nest in marsh grasses that are irregularly flooded Aquatic gleaner Found in fresh, brackish and salt marsh habitats (more common in extensive marshes) Beaufort and Cedar Island areas are two known resident areas Secretive		Significantly Rare[3] High Priority[5]
Common loon *Gavia immer*	Migratory waterfowl Present year-round with highest abundance during spring and fall migrations and winter Piscivorous, forages by surface diving Found in estuaries Raft at night		Moderate Priority[5]
Red-breasted merganser *Mergus serrator*	Migratory waterfowl or sea duck Present during spring and fall migrations and winter Piscivorous, forages by surface diving Found in estuaries and inlet areas	Unknown, may be increasing population[6]	
Canvasback *Aythya valisineria*	Migratory waterfowl, diving duck Present during spring and fall migrations and winter Forages on SAV Found in estuarine and inlet areas	Steady, but below long-term average[6]	Moderate Priority[5]

[1] Population status as designated in the U.S. Shorebird Conservation Plan. [2] Population status as designated in the North American Waterbird Conservation Plan. [3] Status as designated by the North Carolina Natural Heritage Program. [4] Status as designated by the Southeastern Coastal Plains - Caribbean Regional Shorebird Plan. [5] Status as designated by the Partners in Flight Bird Conservation Plan for the South Atlantic Coastal Plain. [6] Status as described in USFWS (2002b).

Data sources: Bent (1964), Brown et al. (2000), Ehrlich et al. (1988), Fussell (1994), Hunter (2001), Hunter et al. (2001), Kushlan and Steinkamp (2001), LeGrand and Hall (1999), Peterson (1980), Root (1988) and USFWS (2002b).

Table 5. Invertebrate evaluation species in the Bogue Banks Shore Protection Project study area utilized in this report for the assessment of resource category determinations.

Species	Ecological Niche	Population Status	Management[∮]
Sand dollar *Mellita quinquiesperforata*	Benthic echinoderm Found in nearshore and offshore areas Feed on organic material Prey for flounder and starfish Reproduce via planktonic fertilization and larvae Move through top layer of sand		
Scolelepsis squamata	Benthic polychaete worm Most abundant polychaete worm in oceanfront beach and inlet areas Filter-feeder Prey for fish and birds		
Moon snail *Polinices* sp.	Benthic gastropod Found in estuarine, nearshore and offshore soft bottom Carnivorous predator		
Star coral *Astrangia danae*	Encrusting epifauna Found in nearshore and offshore hardbottom areas Filter-feeder		
Quilling piddock *Jouanettia quillingi*	Rock-boring, endolithic bivalve Found in nearshore and offshore hardbottom areas Dominant source of bio-erosion at 23-mile Rock offshore Wrightsville Beach		
Coquina clam *Donax variabilis*	Benthic bivalve infauna Found in intertidal inlet and beach areas and nearshore Substrate sensitive (to grain size and geomorphology) Filter-feeder Prey for ghost crabs, birds, and fish		

Mole crab *Emerita talpoida*	Benthic arthropod crustacean infauna Found in intertidal inlet and beach areas and nearshore Sensitive to grain size and geomorphology Filter-feeder Prey for ghost crabs, birds, fish		
Ghost crab *Ocypode quadrata*	Arthropod infauna Found in dunes and dry beach Nocturnal burrower Scavenger Reproduces with planktonic larvae that become amphibious Sensitive to human disturbance and beach cleaning	Less common	
Eastern oyster *Crassostrea virginica*	Sessile bivalve mollusk; keystone species Found in estuaries in intertidal and subtidal habitats Filter-feeder Reef builder and source of carbon sequestration Provides habitat for many other species Long-lived (up to 40 yrs) Spawn from May to September Pelagic larvae, require hard substrate to settle upon Commercially valuable	Concern	NC DMF
Hard clam *Mercenaria mercenaria*	Bivalve mollusk (minimal locomotion) Found dominantly in estuaries and some nearshore Suspension feeder Long-lived (up to 45 yrs) Spawn from May to September, highly fecund Pelagic larvae of very high density in water column Burrower in sandy and vegetated bottoms, often with small rocks or shells, intertidal and subtidal Prey for fish, crabs, starfish, birds and other mollusks Sensitive to turbidity and dredging	Unknown	NC DMF

Bay scallop *Argopecten irradians*	Bivalve mollusk, capable of limited swimming as adults Found in estuaries, especially in eel grass beds and shallow flats Filter-feeder Short-lived (1-2 yrs) Spawn September to November (major) and March to April (minor); hermaphroditic with planktonic fertilization and larvae Prey for rays, blue crab, starfish, and herring gulls Population may be susceptible to high ray predation in Bogue and Core sounds Very young juveniles sensitive to silt, prefer some structure (grass, shell, rock, etc.) on which to settle/attach	Concern	NC DMF
Marsh periwinkle *Littorina irrorata*	Gastropod Found in estuaries on marsh grasses Forages on algae Prey for birds and blue crabs		

∮ Management authority acronyms: ASMFC - Atlantic States Marine Fishery Commission; MAFMC - Mid-Atlantic Fishery Management Council; NC DMF - North Carolina Division of Marine Fisheries; NC WRC - North Carolina Wildlife Resources Commission; NMFS - National Marine Fisheries Service; SAFMC - South Atlantic Fishery Management Council.

Data sources: Alexander et al. (1993), Bowman and Dolan (1985), Donoghue (1999), Fay et al. (1983a, 1983b), Meyer (1994), NC DMF (www.ncfisheries.net), Riggs et al. (1998), Ruppert and Fox (1988), and Turgeon et al. (1988).

SECTION 5. EXISTING FISH AND WILDLIFE RESOURCES

Coastal ecosystems in North Carolina are influenced by a complex interaction of physical, chemical, hydrologic and biological processes. The biological communities present within coastal ecosystems depend on any number of these processes for survival and productivity. Sea turtles, for example, rely upon the physical, chemical and hydrologic parameters of the beach substrate to incubate and hatch eggs. Migratory birds and fish feed on macrofauna living in the wet portions of a beach; the macrofauna are non-uniformly distributed throughout the wet beach depending on precise physical and hydrologic features. Marine epifauna require hard substrates on the seafloor in order to maintain a sessile holdfast. Many fishery resources, both sessile and pelagic, have pelagic larval life stages that depend on tidal currents to transport larvae from spawning to nursery habitats. The influence of physical, chemical and hydrologic parameters on biological resources creates habitats that are dynamic both in space and time.

Many coastal habitats are storm-driven ecosystems, relying upon storms for habitat distribution and availability much like some forest systems are fire-driven ecosystems. Onslow Bay is known for its extensive areas of hardbottoms, which vary from flat algal meadows to high-relief reef complexes (Riggs et al. 1995, Riggs et al. 1996, Riggs et al. 1998). Recent research has shown that these hardbottom areas are continually subject to bioerosion by boring fauna, which breaks down the substrate and creates sediment. These areas then shift from high quality hardbottom habitat to more of a mixed hardbottom-softbottom community. Periodic storms subsequently wash away the bioeroded sediment and restore the hardbottom community (Riggs et al. 1996, Riggs et al. 1998). In a similar manner, pioneering vegetation and bare ground nesting shorebirds and waterbirds rely upon overwash to maintain bare sand habitats at inlets and barrier island interiors. The storm overwash washes away or buries more mature vegetation much the way storm waves remove bioeroded sediment from offshore hardbottoms, restoring the early succession habitat many coastal flora and fauna depend upon.

Bogue Banks Interior

The Bogue Banks present today is estimated to be 4000 to 7000 years old, maintaining a stable to accretionary geographic position for the last 4000 years (Moslow and Heron 1994, Steele 1980). In fact, Moslow and Heron (1994) state that the natural history of Bogue Banks "is unique within the Outer Banks, and contrasts sharply to that of the more common transgressive, storm-overwash-dominated barrier islands" (p. 58). Only the central portion of the island, where the island is narrowest, contains areas subject to overwash and storm breaches (and then only relatively rarely). Hurricane Hazel opened two inlets in eastern Emerald Isle in 1954, one at 2nd Street and the other between 19th and 23rd Streets (Pilkey et al. 1998).

The island's orientation shelters the barrier from northeasters but renders it more vulnerable to hurricanes from the south. During fair weather, the island is considered a low-energy environment with a mean tidal range of 0.89 meters (m; ~3 ft) (Moslow and Heron 1994). The island is one of the largest in North Carolina in terms of length and elevation, with interior elevations reaching 16 m (~52.5 ft) above sea level (Figure 2) and the island is sand-rich,

Figure 2 insert

containing a comparably high volume of sediment along almost its entire length (Moslow and Heron 1994, Steele 1980). New flood zone maps from the state of North Carolina and the Federal Emergency Management Agency (FEMA) for Bogue Banks designate the majority of the island as within the 500 year floodplain, with oceanfront areas subject to wave action and less frequent storm events. A few of the higher beach ridges in Emerald Isle and the Hoop Pole Creek are above the 500 year floodplain. (The new maps can be viewed in Appendix C.)

Most of Bogue Banks consists of shore-parallel beach ridges that are typically vegetated with maritime forest. Where the ridges are shore-oblique or curved, they generally indicate the historic presence of an inlet (Moslow and Heron 1994). Cheeseman Inlet, for example, was historically present in eastern Pine Knoll Shores/western Atlantic Beach and may have generated the recurved beach ridges prominent at the Theodore Roosevelt State Nature Reserve. The ridges are geomorphic features that determine the distribution of maritime forest and wetland communities on the island.

The maritime forest on Bogue Banks is the most abundant remaining on a North Carolina barrier island. Several of these tracts remain intact (Table 6), but by and large the maritime forest on the island is becoming fragmented as development continues. Individual property development tends to build structures within the forest, such as that along Oakleaf Road in Pine Knoll Shores, whereas larger scale developments may clear the vegetation for development (e.g., the Atlantic Beach amusement park or Bogue Banks Country Club golf course (Pilkey et al. 1998)). The dense maritime forest provides valuable habitat for migratory and resident songbirds, mammals, and reptiles.

Table 6. Significant tracts of maritime forest on Bogue Banks that are currently intact.

Area	Responsible Party	Approximate Area (acres)
Fort Macon State Park	NC Division of Parks and Recreation	414
Theodore Roosevelt State Natural Area	NC Division of Parks and Recreation	301
Hoop Pole Creek	North Carolina Coastal Federation (NCCF)	32
Regional Beach Access and State Park	Town of Indian Beach and NC Parks and Recreation	26
Emerald Isle Stormwater Management Site	Town of Emerald Isle and NCCF	41
Indian Beach Maritime Forest	Unknown	136
Salter Path Maritime Forest	Unknown	65

The troughs in between the beach ridges often contain freshwater wetlands, also oriented in a linear, east-west orientation. Table 7 lists the wetlands found on Bogue Banks by the National Wetlands Inventory (NWI) Program in 1983. Over 2000 acres of wetlands are distributed along the estuarine shoreline and interior portions of the barrier island. Excavated ponds and canals in several subdivisions accounted for another 165 acres as of 1983. Forested wetlands, both deciduous and evergreen, are found on approximately 167 acres of the island, concentrated in western and central Emerald Isle. An analysis conducted for the Town of Emerald Isle, which recently purchased a 41 acre tract immediately west of the Route 58 bridge, found that these forested wetlands were very high quality. Ecological evaluations of the property determined that the swamp forest was dominated by red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), red bay (*Persea palustris*), black willow (*Salix nigra*), and a thick understory of American holly (*Ilex opaca*), red bay, Atlantic white cedar (*Chamaecyparis thyoides*) and wax myrtle (*Myrica cerifera*). These wetlands areas support a diversity of wildlife, including American alligator (*Alligator mississippiensis*), white-tailed deer (*Odocoileus virginianus*), Carolina wren (*Thryothorus ludovicianus*), red-bellied woodpecker (*Melanerpes carolinus*), summer tanager (*Piranga rubra*), and yellow-bellied sapsucker (*Sphyrapicus varius*). Functional analyses of the wetlands found the estuarine marsh to be in the 93rd percentile of biological functionality, the maritime swamp forest ranked in the 73rd percentile, and the freshwater marsh scored in the 54th percentile (Moffatt and Nichol 2000).

Other landscape cover types present on Bogue Banks include scrub-shrub, professionally landscaped areas, impervious surfaces and bare ground. Scrub-shrub areas are commonly found adjacent to or intermixed with maritime forest (Figure 3). Approximately 328 acres of Bogue Banks is covered by scrub-shrub wetland communities (Table 7). Landscaped and impervious areas are indicative of development and generally provide significantly less habitat value to fish and wildlife resources than natural vegetation communities. Bare ground areas are concentrated along the oceanfront beaches and inlet areas.

Several areas on Bogue Banks have been set aside for public use and/or conservation. Fort Macon State Park in Atlantic Beach borders Beaufort Inlet. This ~414 acre park contains an historic fort and associated cultural resources, multiple dune ridges with dense forest and scrub-shrub vegetation, and extensive wetland communities on the soundside. The Theodore Roosevelt State Natural Area contains ~301 acres of maritime forest and estuarine wetlands along with one of the North Carolina Aquariums. This tract has also been designated as an Otherwise Protected Area (OPA) under the Coastal Barrier Resources Act (CBRA) by the United States Congress. Hoop Pole Creek in Atlantic Beach is a ~32 acre preserve of maritime forest, tidal creeks and estuarine wetlands purchased by the North Carolina Coastal Federation (NCCF) with a Clean Water Management Trust Fund grant. The Town of Indian Beach, the North Carolina Divisions of Parks and Recreation and Coastal Management own tracts totaling ~25 acres near Mile Marker 10 that functions as a state park and Regional Beach Access facility. The park contains densely vegetated maritime forest and scrub-shrub communities on a series of beach ridges directly adjacent to the oceanfront beach. The Town of Emerald Isle maintains several small parcels of land as local parks and public accesses to Bogue Sound, and may add a recreational component to a 41 acre tract of maritime forest and forested wetlands purchased for a stormwater treatment system in the western part of the town.

Table 7. Areas on or contiguous to Bogue Banks classified as wetlands on 1983 National Wetlands Inventory (NWI) maps. Wetland classifications are after Cowardin et al. (1979).

NWI Category	Description	Area (acres)
PSS1C	Palustrine, scrub-shrub, broad-leaved deciduous, seasonally flooded	1.05
PSS7A	Palustrine, scrub-shrub, evergreen, temporarily flooded	5.29
PFO7C	Palustrine, forested, evergreen, seasonally flooded	166.81
PEM1C	Palustrine, emergent, persistent, seasonally flooded	0.63
E1UB2M	Estuarine, subtidal, unconsolidated bottom, sand, irregularly exposed	10.23
E2EM1N	Estuarine, intertidal, emergent, persistent, regularly flooded	933.94
E2EM1P	Estuarine, intertidal, emergent, persistent, irregularly flooded	86.80
E2SS1P	Estuarine, intertidal, scrub-shrub, broad-leaved deciduous, irregularly flooded	158.23
E2SS7P	Estuarine, intertidal, scrub-shrub, evergreen, irregularly flooded	164.19
E2US2M	Estuarine, intertidal, unconsolidated shore, sand, irregularly exposed	478.92
E2US2P	Estuarine, intertidal, unconsolidated shore, sand, irregularly flooded	9.65
	Total area of wetlands	**~2020 acres**

Figure 3. Bogue Banks has over 2000 acres of wetlands such as these in low-lying areas in between dune ridges. This predominantly scrub-shrub wetland is in Pine Knoll Shores near Mile Marker 4. Photo taken in March 2002 by USFWS.

Bogue Banks Oceanfront Shoreline

Bogue Banks contains approximately 24 miles of southward-facing oceanfront beaches. The oceanic shoreline can be divided into several ecological niches: the dune; dry beach; wet beach; and shoreface. These communities have been described in USFWS (1999), USFWS (2000a), USFWS (2000b), USFWS (2001) and USFWS (2002a), which are incorporated here. The long-term erosion rates for the Bogue Banks oceanfront average less than 3 feet per year, with most of the island listed at the minimum of 2 feet per year (NC DCM 1992).

The comparatively high sediment volume composing the interior of the barrier island creates one of the highest dune ridges in North Carolina along the oceanic beach. The northern, or landward, side of the dune system is generally vegetated by dense maritime forest or scrub-shrub along Bogue Banks. In western and central Emerald Isle, eastern Indian Beach, Pine Knoll Shores and portions of Atlantic Beach, the dune system consists of multiple dune ridges reaching 4 to 5 m (~13 - 16.4 ft) in elevation. The southernmost dune ridge typically has an erosional scarp facing the beach. These dune scarps supply clean, quartz sand to the beach during storm events, naturally dissipating wave energy.

The dune face adjacent to the beach provides habitat for ghost crabs (*Ocypode quadrata*) and other invertebrate species. This ecological community has been disrupted by extensive beach scraping, or bulldozing, along the majority of the island's beaches. The scraping has degraded the biological community naturally found in the dune scarp and dune toe, suppressing the abundance and distribution of fauna such as ghost crabs (Conaway 2000; Peterson et al. 2000; Peterson and Manning 2001).

The dry beach is found between the dune toe or scarp and the mean high water (MHW) line. Along virtually the entire length of Bogue Banks the dry beach is narrow and occasionally nonexistent during spring high tides or minor storm events. This ecological niche provides habitat for several species of amphipods, nesting sea turtles, burrowing ghost crabs and loafing shorebirds and colonial waterbirds. Authorized federal dredge disposal projects in Atlantic Beach, Pine Knoll Shores and Emerald Isle have periodically disturbed the dry beach ecosystem, with varying degrees of impact (Lindquist and Manning 2001; Peterson et al. 2000; Reilly and Bellis 1978).

Most recently the Towns of Pine Knoll Shores, Indian Beach and Emerald Isle received a Regulatory permit from the Corps to dredge sediment offshore of the central part of the island and place the material along 17 miles of beach from the Pine Knoll Shores-Atlantic Beach town line to western Emerald Isle. The first phase of this project was constructed from November 2001 to April 2002 and covered between 6 and 7 miles of beach in Pine Knoll Shores, Indian Beach and Salter Path. Phase I was prematurely halted in April due to the taking of five sea turtles by the dredge equipment, shortening the length of beach impacted. The sediment used in this project is not ecologically compatible with the native beach sediments of Bogue Banks, and the sandy beach fauna have not recovered in the beach fill as of this time (Appendix G).

In 2000 there were 17 sea turtle nests and 6 false crawls recorded along Bogue Banks' beaches.

All but two of the nests were of loggerhead sea turtles (*Caretta caretta*); the other two were green sea turtle nests (*Chelonia mydas*). In 2001 there were 21 nests (all loggerhead sea turtles) in Emerald Isle and 19 false crawls. By comparison, Shackleford Banks recorded 19 loggerhead sea turtle nests and 8 false crawls in 2001 and 21 nests with 5 false crawls in 2000. Hammocks Beach to the west reported 9 loggerhead sea turtle nests and 15 false crawls in 2001 and 19 loggerhead nests with 24 false crawls in 2000. The 2002 sea turtle nesting season documented 13 loggerhead nests in Emerald Isle, 5 in Pine Knoll Shores and 1 in Indian Beach/Salter Path; there were 19 false crawls along Bogue Banks during the same period (12 in Emerald Isle and 7 in Pine Knoll Shores).

The oceanfront beaches of Bogue Banks have not recorded any colonial waterbird or shorebird nesting in recent memory. Birds may use the beach for loafing or foraging, however.

The native beach sands of Bogue Banks are light brown in color with periodic patches of black where heavy minerals (e.g., garnet, magnetite, ilmenite) have been deposited by storm or spring tide waves on the normally dry beach (Figure 4). The newly filled beaches in Pine Knoll Shores and Indian Beach are noticeably different in color than the native beaches, with a gray to black coloration (Figure 5). The native and newly artificial beaches differ mineralogically as well, with the native (dry) beaches dominated by quartz with minimal well-rounded marine shells and

Figure 4. Black heavy minerals (including garnet) occur in patches along the beaches of Bogue Banks, as on this stretch of Emerald Isle near Mile Marker 15 on May 30, 2002. Both the black and light brown (quartz) sands are native. Note the very narrow to nonexistent dry beach; this photograph was taken near high tide during fair weather.

Figure 5. The color contrast between the native sediments of Bogue Banks' beaches on the right and the artificial beach fill placed on the beach during the winter of 2001-02 on the left is pronounced. The native sands are light brown with low shell content while the new fill is gray with a high shell content. The view is towards the west from the state park in Indian Beach near Mile Marker 10 on May 29, 2002.

quartz disc-shaped pebbles (Figure 6) while the artificial fill is dominated by angular estuarine shells that have been stained black by iron in an anaerobic environment (Figure 7). Using the visual percentage method of Terry and Chilingar (1955), the native dry beaches of Bogue Banks tend to have 0 to 5 % shell content on the surface and the newly filled dry beaches range from 0 to 100%.

The repopulation of the new beach fill by ghost crabs allows for a unique comparison of the new sediments versus the native sediments. The local project did not construct artificial dunes and the construction only minimally disturbed the dune toe and face. Thus the fill ranges from a few inches to less than 24 inches thick at the landward portion of the dry beach. Ghost crab burrows can exceed 48 inches in depth and have several exits on the beach surface. Figure 8 shows how the ghost crabs have excavated burrows through the new fill along the landward most 10 m (33 feet) of the dry beach, depositing native sediments on top of the new fill. The color contrast between the two sediment types is striking and lends a colonial look to the ghost crab population.

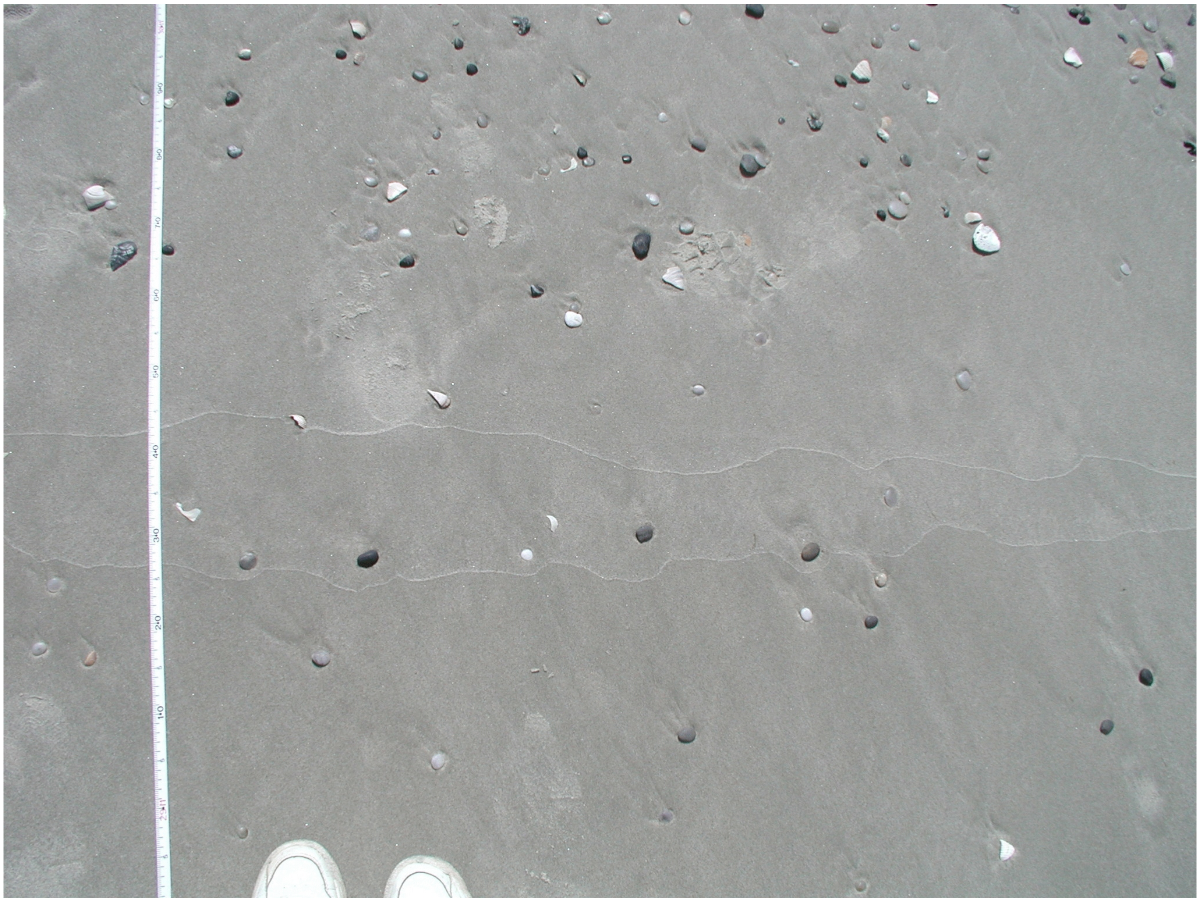


Figure 6. The natural beach at Mile Marker 4 in Atlantic Beach is dominated by light brown quartz sand with less than 5% disc-shaped, well-rounded quartz pebbles and shell fragments. This photograph was taken of the surface sediments in the intertidal zone, 31 meters from the dune toe, on March 14, 2002. The two wavy lines are swash marks left by the outgoing tide.

The noticeable differences between the natural and artificial beaches of the project area persist in the wet beach, or the area subject to daily tidal flux. This ecological niche is subject to wave action which creates alternating periods of subaqueous and subaerial conditions. The fauna adapted to this environment are concentrated in the top 5 to 10 centimeters (cm; ~2-4 inches) (Dr. C.H. Peterson and L. Manning, UNC-Institute of Marine Sciences, personal comm.) and are sensitive to the grain size, geomorphology and swash energy of the intertidal zone (Alexander et al. 1993; Donoghue 1999). Therefore the fauna are patchily distributed depending upon the specific physical and hydrologic characteristics at any given location along and across the beach (Bowman and Dolan 1985; Donoghue 1999; Lindquist and Manning 2001).

Along Bogue Banks, the wet beach infauna is dominated by polychaete worms, coquina clams (*Donax variabilis*) and mole crabs (*Emerita talpoida*) (Diaz 1980; Lindquist and Manning 2001; Peterson et al. 2000; Peterson and Manning 2001; Reilly and Bellis 1978). Predators foraging on the infauna include shorebirds such as sanderlings (*Calidris alba*) and willets (*Catoptrophorus semipalmatus*) and surf zone fish including Florida pompano (*Trachinotus carolinus*) and Gulf kingfish (*Menticirrhus littoralis*) (Lindquist and Manning 2001; Peterson et al. 2000; Peterson and Manning 2001).

The native wet beaches of the project area often have depressed infaunal populations due to beach scraping and beach fill activities relative to pre-project levels (Peterson et al. 2000; Peterson and Manning 2001; Reilly and Bellis 1978). The substrate providing the habitat for the infauna is naturally light brown quartz sand with patches of well-rounded, marine shell hash and black to purple heavy minerals. The new beach fill in Pine Knoll Shores and Indian Beach, on the other hand, consists of 0 to 100% angular, estuarine shell hash that tends to be black in color (Figure 7). Large oyster (*Crassostrea* sp.) and clam (*Mercenaria* sp.) shells are preferentially winnowed from the sand-sized quartz sediment by the waves, creating patches of pure shell or quartz on the wet beach. The oyster and clam shells range from 4.0 to 13.2 cm (~1.6-5.2 in) in size and 38 to 497 grams (g) in weight (Figure 9). Where quartz has been sorted by the waves, angular shell hash is commonly within 5 cm (~2 in) of the surface.

The upper part of the current wet beach in Pine Knoll Shores and Indian Beach is dominated by beach fill that has not yet been sorted by the waves. This substrate is a mixture of angular shells and quartz sand that is more resistant to sorting by the waves than the natural sediments; spring

Figure 7. The artificial beach fill placed along the oceanfront beaches of Pine Knoll Shores and Indian Beach during the winter of 2001-02 is dominated by large, angular shell fragments. Most of the shells seen here are clams (*Mercenaria* sp.) normally found in estuaries. The shells have been stained bright orange, gray and black by burial in marsh muds and replacement of portions of the calcium carbonate by iron. Photo taken March 2002 by USFWS.

tides and minor storm events have generated periodic scarps in the beach fill as a result (Figure 10). These scarps allow for a look at the internal structure of the new beach fill and the source of the sediments being sorted on the wet beach.

The portion of the beach that remains wet during all tidal stages is the shoreface. This ecological zone supports a diverse faunal community of infaunal invertebrates and surf zone fishery resources. Bogue Banks tends to have a single or double sand bar and trough bathymetry, generating several ecological niches. This area extends from 0 to approximately 9.1 m (30 ft) of water depth along Bogue Banks.

The local beach scraping and beach fill project have minimally disturbed the aqueous system because construction was limited to areas above the mean low water (MLW) line. Nevertheless, the shoreface's surface sediment within the Pine Knoll Shores-Indian Beach beach fill area appears to be shifting to a higher concentration of shells being winnowed out of the fill. Research is ongoing to monitor large-scale modifications to this habitat resulting from the local project.

Figure 8. Ghost crabs (*Ocypode quadrata*) have burrowed through the relatively thin layer of new beach fill, excavating native sediments (light brown) from burrows and depositing the sands on top of the darker artificial fill. The ruler is 15 cm long for scale and the photograph taken May 29, 2002, near Mile Marker 6 in Pine Knoll Shores. The dune is to the right, outside the frame.

Figure 9. Large, angular clam and oyster shells are being preferentially sorted by the waves from the sand-sized quartz grains in the new beach fill in Pine Knoll Shores and Indian Beach. The ruler is 15 cm for scale and the outgoing swash is visible in the upper left of the photograph. Photo taken May 30, 2002, by USFWS.

The aquatic resources present near the beach in the shoreface, or surf zone, area support a traditional commercial fishery in Salter Path. Although specific landings data are confidential, the fall months appear to be the period when beach seining and gill netting is used along this stretch of beach to harvest fish. Thus the fishery resources in the nearshore (or shoreface) zone are abundant enough to support commercial harvest.

Figure 10. The new beach fill in Pine Knoll Shores is more resistant to higher tides and minor storm waves, forming low scarps as seen here in Pine Knoll Shores near Mile Marker 5.5 on May 29, 2002. The ruler is 15 cm high for scale and Twin Pier is in the background.

Bogue Banks Estuarine Shoreline

The northern shoreline of Bogue Banks along Bogue Sound consists of stabilized and natural shoreline segments. The soundside shoreline consists of approximately 38 miles of brackish marsh, sandy beach, artificially stabilized shoreline types (e.g., riprap, bulkheads, groins), and mixed shorelines of intermixed marsh and stabilized areas. The shoreline was categorized into these four categories remotely using 1998 color aerial photography and ground-truthed in the field (in May 2002).

Fringing marsh areas range from less than 5 feet to over 100 feet wide and may be adjacent to landscaped yards, maritime forest or hard stabilization (Figure 11). This type of shoreline is the most abundant along the Bogue Banks soundside shoreline, covering 50.9 ± 0.8% of the shoreline from Fort Macon to The Pointe.

Figure 11. An example of shoreline categorized as fringing *Spartina* spp. marsh from central Emerald Isle on Bogue Sound. This particular reach is bordered by forested areas. Photo taken May 2002 by USFWS.

Figure 12. This segment of shoreline along Bogue Sound in western Emerald Isle is categorized as a sandy beach shoreline. Bogue Inlet and the Atlantic Ocean are towards the top of the photograph and Bogue Sound at the bottom. Photo taken May 2002 by USFWS.

Sandy beaches are minimal along the Bogue Sound shoreline on Bogue Banks (7.2 ± 0.8%), especially when compared to Shackleford Banks to the east which is dominated by sand beaches along its estuarine shoreline. The sand beaches on Bogue Banks are virtually all at either end of the island near the inlets (Figure 12).

The remaining portion of the estuarine shoreline consists of artificially stabilized and mixed shorelines. Artificially stabilized areas range widely in type and are constructed and maintained by private property owners (Figure 13). Areas were classified as mixed if the proportion of properties stabilized alternated with natural marsh shorelines were roughly equal. Approximately equal portions of the 38 miles of estuarine shoreline were classified as artificially stabilized (21.6 ± 0.8%) and mixed (20.3 ± 0.8%).

Figure 13. Shoreline segments with both stabilized and natural estuarine shorelines were categorized as mixed. The developed shoreline to the left in the photograph was classified as mixed with some reaches stabilized and others not. The natural shoreline on the right was categorized as a marsh shoreline type. Photo taken in western Emerald Isle in May 2002 by USFWS.

The North Carolina Division of Marine Fisheries has designated one area along the estuarine shoreline of Bogue Banks as fishery nursery areas (Figure 14). Archer Creek is located in Emerald Isle and is oriented in an east-west direction, draining to the east. Thus the nursery area is sheltered from winds out of the west, north and south. The nursery area covers 18 acres that are classified as intertidal emergent wetlands by the National Wetlands Inventory (NWI) program and salt/brackish marsh by the North Carolina Division of Coastal Management (NC DCM).

The North Carolina Coastal Federation (NCCF) has purchased ~32 acres at Hoop Pole Creek for conservation and restoration of natural ecosystems in this area. The preserve is located at Mile Marker 3 and is adjacent to shopping centers on its western and southern boundaries. The group has undertaken restoration of oyster beds along this stretch of shoreline and regularly conducts environmental education programs on an interpretive trail through the tract.

Figure 14. The Archer Creek fishery nursery area in Emerald Isle, highlighted in magenta. The Atlantic Ocean is at the bottom of the image and Bogue Sound at the top. The nursery area encompasses ~18 acres of brackish marsh wetland habitat. The green lines parallel to the estuarine shoreline indicate marsh shoreline types and blue lines indicate mixed shoreline types. Orange-red areas are maritime forest, white areas bare sand or impervious surfaces, and black areas open water. Image is from 1998 U.S. Geological Survey Mr. SID color infrared data for the Swansboro quadrangle.

Bogue Sound

Bogue Sound is the body of shallow water to the north of Bogue Banks, separating the barrier island from the mainland of Carteret County. The sound is bordered by Bogue Inlet and the White Oak River to the west and Beaufort Inlet and the Newport River to the east. The Atlantic Intracoastal Waterway (AIWW) traverses the northern portion of Bogue Sound in an east-west orientation. Salinity varies in the sound, with the highest levels closest to the two inlets where the tidal influence is strongest. The North Carolina Division of Water Quality (NC DWQ) has designated Bogue Sound as having Outstanding Resource Waters (ORW) due to their high quality.

The sound is of moderate size for North Carolina (with a maximum fetch of ~23 miles), larger than any open-water sound to the south but covering less area than Albemarle or Pamlico Sounds to the north (which have maximum fetches of 30-70 miles). The southern portion of the sound along Bogue Banks contains several areas of sand shoals and *Spartina* spp. marsh (Figure 15). Shellfish beds and submerged aquatic vegetation (SAV) occur throughout the sound. Comparatively deeper waters allow navigational use and transport of larval stages of fishery resources.

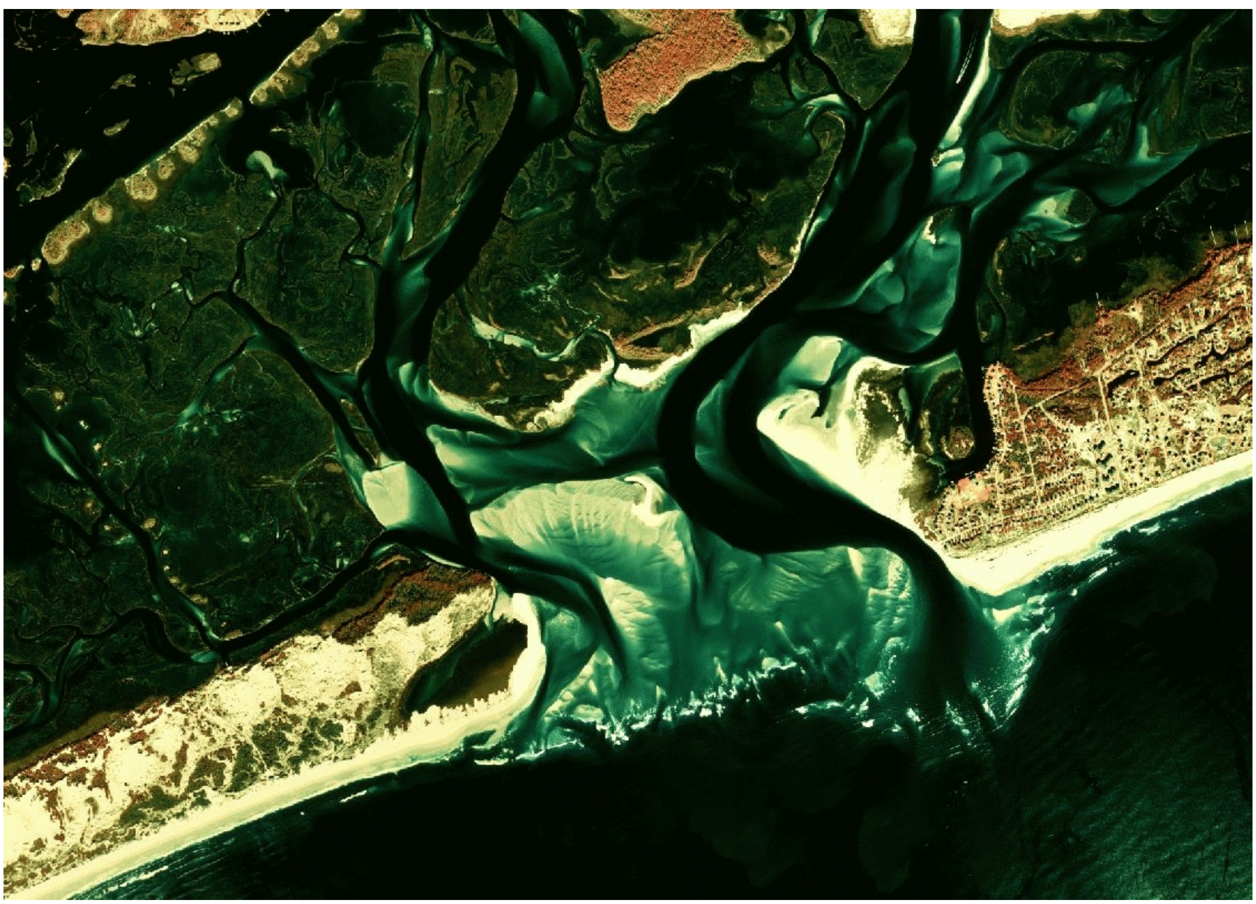


Figure 15. An aerial view of Bogue Inlet in 1998. Note the extensive sand shoals within the inlet. Emerald Isle is to the right and Hammocks Beach State Park to the left. Bogue Sound is at the upper right of the photograph. Photo courtesy of the US Geological Survey.

There are 10 active and 33 inactive dredge spoil islands along the AIWW between Mile Markers 29 and 78 from Beaufort to Bogue Inlets. These dredge spoil islands are artificially created and currently cover an estimated 387 acres. The spoil islands tend to have large areas above sound waters and many are over 50 years old. The older islands support mature vegetation (trees and scrub-shrub thickets), which provide habitat for migratory songbirds. Younger and more active islands tend to have large areas of bare sand, which provide nesting habitat for colonial waterbirds (Everhart et al. 1980). Brandt Island is the largest of these at ~80 acres and is connected to Fort Macon State Park by marsh and wetland areas. This disposal island receives dredge disposal material from the Morehead City State Port and is pumped out for disposal on Atlantic Beach every 8 to 10 years.

An unnamed skipper (*Atrytonopsis* sp.) has recently been discovered on Brandt and Radio Islands at the eastern end of Bogue Sound. Genetic studies are currently underway to determine if the skipper is endemic to this area or a previously known species. The habitat requirements for the skipper are also under study. Colonial waterbirds known to nest on islands in Bogue Sound, Bogue Inlet and Beaufort Inlet are listed in Table 8. Most of these species nest in colonies in bare ground areas, often abandoning an area once vegetation matures and eliminates wide expanses of bare ground (Everhart et al. 1980). The Natural Heritage Program has designated the natural and dredge spoil islands in Bogue Sound as a Significant Natural Heritage Area for shorebirds and colonial waterbirds.

The sand shoals within Bogue Sound provide habitat for foraging, staging and loafing shorebirds and colonial waterbirds, protection for SAV beds from predominant winds, and shelter for fishery resources. In any individual year, there may be upwards of thousands of colonial waterbirds nesting within or adjacent to Bogue Sound (Table 8). Some of the shoal areas are byproducts of navigational dredging while others are natural accumulations of sand. Brandt Island used to support large colonies of nesting terns, but its nesting value has decreased as the island has enlarged, stabilized with vegetation, and provided habitat for mammalian predators (D. Allen, NC WRC, pers. comm.). Everhart et al. (1980) found nesting colonies averaged less than 6% vegetative cover for gull-billed terns and black skimmers and 26% for common terns. The preferred elevation of the bare ground nesting sites was between 1 and 3 m (3.3-9.8 ft) above surrounding waters (Everhart et al. 1980).

Bogue Sound also provides diverse aquatic resources. Over 6100 acres of SAV were located in the sound in 1988 or 1993 (NOAA 2002). These beds have been designated as Essential Fish Habitat (EFH) by the South Atlantic Fishery Management Council (SAFMC) for their high value to blue crab (*Callinectes sapidus*), juvenile fish, and shrimp (*Penaeus* sp.). All five species of sea turtles found in North Carolina waters (Epperly et al. 1995) and the West Indian manatee (*Trichechus manatus*), all Federally-protected species, may forage in Bogue Sound during warmer summer months. As herbivorous and/or omnivorous species, these aquatic species forage upon SAV beds for nourishment. Figure 16 shows the distribution of the SAV beds surveyed by NOAA.

Table 8. Species of colonial waterbirds known to nest on islands within Bogue Sound, Bogue Inlet and Beaufort Inlet; the most recent year to record nesting; and the maximum number of nests in any recorded colony. Data from the NC WRC.

Waterbird Species	Recent Nesting Years	Colony Size Range (number of nests in any colony)
Common tern *Sterna hirundo*	1977 - 2001	1 - 576
Least tern *Sterna antillarum*	1977 - 2001	1 - 200
Gull-billed tern *Sterna nilotica*	1977 - 1993	2 - 175
Forster's tern *Sterna forsteri*	1995	9
Black skimmer *Rynchops niger*	1977 - 2001	1 - 182
Black-crowned night-heron *Nycticorax nycticorax*	1976 - 2001	1 - 72
Cattle egret *Bubulcus ibis*	1975 - 2001	8 - 689
Great egret *Casmerodius albus*	1975 - 2001	1 - 334
Green heron *Butorides striatus*	1975 - 1995	1 - 18
Little blue heron *Egretta caerulea*	1975 - 2001	8 - 362
Snowy egret *Egretta thula*	1975 - 2001	4 - 247
Tricolored heron *Egretta tricolor*	1975 - 2001	8 - 920
Great blue heron *Ardea herodias*	1977	1
Glossy ibis *Plegadis falcinellus*	1989 - 1995	4 - 5

Figure 16 insert

There are approximately 808 acres of freestanding saltwater and brackish marsh in Bogue Sound that is not contiguous to the mainland or Bogue Banks. Most of the marsh is adjacent to disposal islands and is more abundant at the eastern and western ends of the sound than in the central portion. The NC DCM delineated an additional ~339 acres of scrub-shrub wetlands in the sound associated with the marsh and disposal island complexes.

Several estuarine areas along the northern boundary of Bogue Sound have been designated as fishery nursery areas by the North Carolina Division of Marine Fisheries (NC DMF). These include Goose Creek (~77 acres), Broad Creek (~48 acres) and Gales Creek (~47 acres). In addition, the NC DMF maintains permanent easements on over 4700 acres of Bogue Sound waters and estuarine areas, all located adjacent to the soundside shoreline of Bogue Banks.

Bogue Sound contains many areas closed to shellfishing. The Shellfish Sanitation Branch of the North Carolina Division of Environmental Health has closed several local marinas and harbors to shellfishing, as well as large areas near Morehead City, Beaufort, Swansboro, Pine Knoll Shores, Salter Path, and the Atlantic Beach causeway. On the southern side of Bogue Sound, along Bogue Banks, closed shellfishing areas include Hoop Pole Creek, Beacons Reach, and Archer Creek. Other closed shellfishing areas in Bogue Sound are Peletier Creek, Spooners Creek, Gales Creek, Broad Creek, Sanders Creek, Deer Creek, and Hunting Island Creek. The White Oak River estuary contains conditionally approved shellfish harvesting areas while significant portions of the Newport River estuary to the east is largely closed to shellfishing.

Commercial fishery landings from Bogue Sound average 539,680 lbs for an average annual value of $ 672,512. Table 9 lists the two dozen fishery species, their average catch and commercial value from 1994 to 2001 for Bogue Sound. Blue crab, shrimp, hard clams (*Mercenaria mercenaria*), spot (*Leiostomus xanthurus*), mullet (*Mugilidae* sp.), southern flounder (*Paralichthys lethostigma*), and bay scallop (*Argopecten irradians*) are the largest annual catches by weight from Bogue Sound (NC DMF, unpublished data; Appendix E).

The diverse ecological resources of Bogue Sound also support a successful ecotourism industry. Several outfitters rent kayaks and canoes for both guided and individual trips through the marshes, to disposal islands, estuarine beaches and shallow waters. Bird watching, dolphin watching, seining, and shellfishing are all advertised attractions for the outfitters. Other entities heavily utilize the area for nature field trips, including the North Carolina Coastal Federation (NCCF), Hammocks Beach State Park staff, the Rachel Carson Estuarine Research Reserve west of Beaufort Inlet, and the marine labs at Duke University, the Institute of Marine Sciences at the University of North Carolina-Chapel Hill (IMS-UNC) and the National Oceanic and Atmospheric Administration (NOAA). The latter three utilize the ecological resources of Bogue Sound and adjacent areas extensively for scientific research.

Table 9. Commercial fisheries landings from Bogue Sound, 1994 to 2001. Data are provided by the North Carolina Division of Marine Fisheries and represented in state fiscal years (July 1 through June 30). See Appendix E for landings and value data by year.

Species	Average Landings (lbs)§	Average Value §
Bluefish	3,715	$ 982
Butterfish	479	$ 187
Croaker	914	$ 246
Black drum	990	$ 233
Red drum	2,982	$ 2,961
Southern flounders	19,113	$ 31,817
Kingfishes (sea mullet)	805	$ 734
Menhaden bait	7,579	$ 3,232
Minnows	2,261	$ 2,666
Mullets	114,156	$ 86,204
Pigfish	1,012	$ 210
Gray seatrout	1,241	$ 676
Spotted seatrout	7,684	$ 9,041
Sheepshead	473	$ 164
Spanish mackerel	3,507	$ 2,126
Spot	67,621	$ 26,307
Blue crab, hard	205,334	$ 135,475
Blue crab, peeler	4,132	$ 6,576
Blue crab, soft	786	$ 3,136
Stone crab	657	$ 1,689
Shrimp (unclassified, heads on)	27,961	$ 53,563
Brown shrimp†	6,965	$ 8,980
White shrimp†	17,260	$ 33,796
Pink shrimp†	1,517	$ 3,673
Hard clam (meats)	35,887	$ 225,302

Arc clam	208	$ 584
Eastern oyster	6,896	$ 27,804
Whelks/conchs (meats)	2,009	$ 1,921
Bay scallop (meats)	13,748	$ 46,085
Total for all species[▽]	**539,680**	**$ 672,512**

[§] Averages do not include confidential data.
[†] Brown, white and pink shrimp categories contain data from 1999-2001.
[▽] Total includes species categories not listed in table.

Bogue Inlet

The fish and wildlife resources in and around Bogue Inlet are abundant and diverse. Sandy, tidal inlets in North Carolina provide valuable habitat to migratory shorebirds, colonial waterbirds, marine mammals and reptiles, anadromous fish, and estuarine and marine fisheries. The inlets also serve as a hydrologic pathway connecting marine and estuarine resources including wetlands, saltwater marsh, submerged aquatic vegetation (SAV), fish nursery areas, and both freshwater and marine fishery spawning areas. Many fishery resources have pelagic early life stages that rely upon tidal currents at inlets to passively transport larvae from spawning to juvenile development areas.

Several federally-protected species are present in the Bogue Inlet area depending on the season. Federally-threatened and endangered sea turtles use the inlet as a pathway to estuarine foraging areas and nest on project area beaches. The West Indian manatee (*Trichechus manatus*), a federally-endangered species, may be present in or around the project area from June to October, foraging in estuarine areas. Manatees have been sighted in July 2000 in the Atlantic Intracoastal Waterway north of State Highway 101, August 1999 near Calico Creek, August 1999 along the Beaufort waterfront, June 1998 near Hammocks Beach State Park, August 1994 near Sportsman Pier in Atlantic Beach, August 1994 near the U.S. Coast Guard Station at Fort Macon, November 1992 in Barden Inlet, October 1990 in Peltier Creek, and August 1983 in the nearshore off the western end of Shackleford Banks.

The federally-threatened piping plover (*Charadrius melodus*) may be present in the proposed project area year-round for nesting, migration or overwintering. The Service has designated Bogue Inlet, as well as Shackleford Banks and the Rachel Carson National Estuarine Research Reserve, as critical habitat for overwintering piping plovers. Service personnel identified 11 piping plovers, including one believed to be from the Great Plains population of Saskatchewan and another from Prince Edward Island, Canada, using the inlet as a migratory stopover site on October 13, 2002, illustrating the inlet's comparably high use by piping plovers in North Carolina.

The project area has been designated with numerous management characterizations reflecting its high resource value. The waters to the east and west of the navigational channel have been designated as Outstanding Resource Waters (ORW) by the North Carolina Division of Water Quality (NC DWQ). The Natural Heritage Program has delineated several Significant Natural Heritage Areas within the project area, including Huggins and Dudley Islands, West End Beach on Emerald Isle, Hammocks Beach State Park to the west of the inlet, extensive areas within Bogue Inlet and Bogue Sound as bird islands, Hawkins Island to the northwest, and Jones Island and Cedar Point Marshes in the White Oak River to the north of the inlet (Figure 17). Tidal inlets have also been designated as Habitat Areas of Particular Concern (HAPC) for red drum (*Sciaenops ocellatus*), penaeid shrimp and the snapper-grouper complex by the South Atlantic Fishery Management Council (SAFMC). The Service has designated critical habitat for overwintering piping plovers at Bogue Inlet. The United States Congress has designated most of Bogue Inlet as Otherwise Protected Area (OPA) NC-06P under the Coastal Barrier Resources Act, coincident with the boundaries of Hammocks Beach State Park.

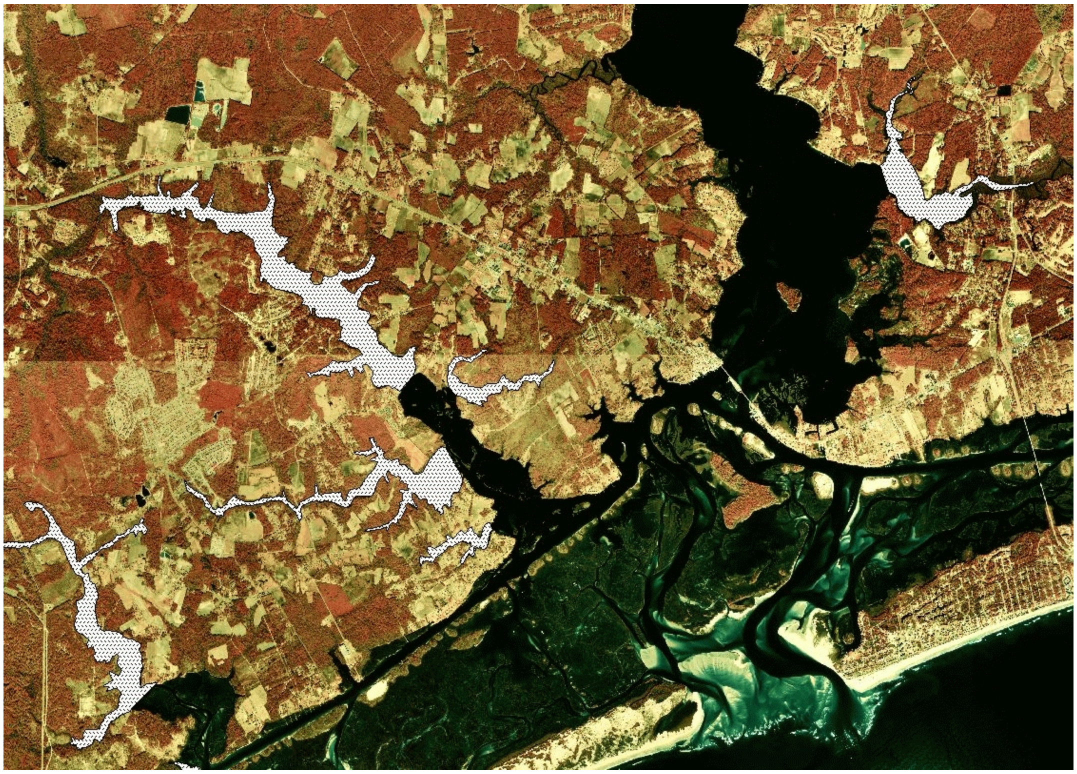


Figure 17. Fishery nursery areas in and around the White Oak River (upper right) and Bogue Inlet (lower right) are highlighted in white and black. Data from NC Division of Marine Fisheries.

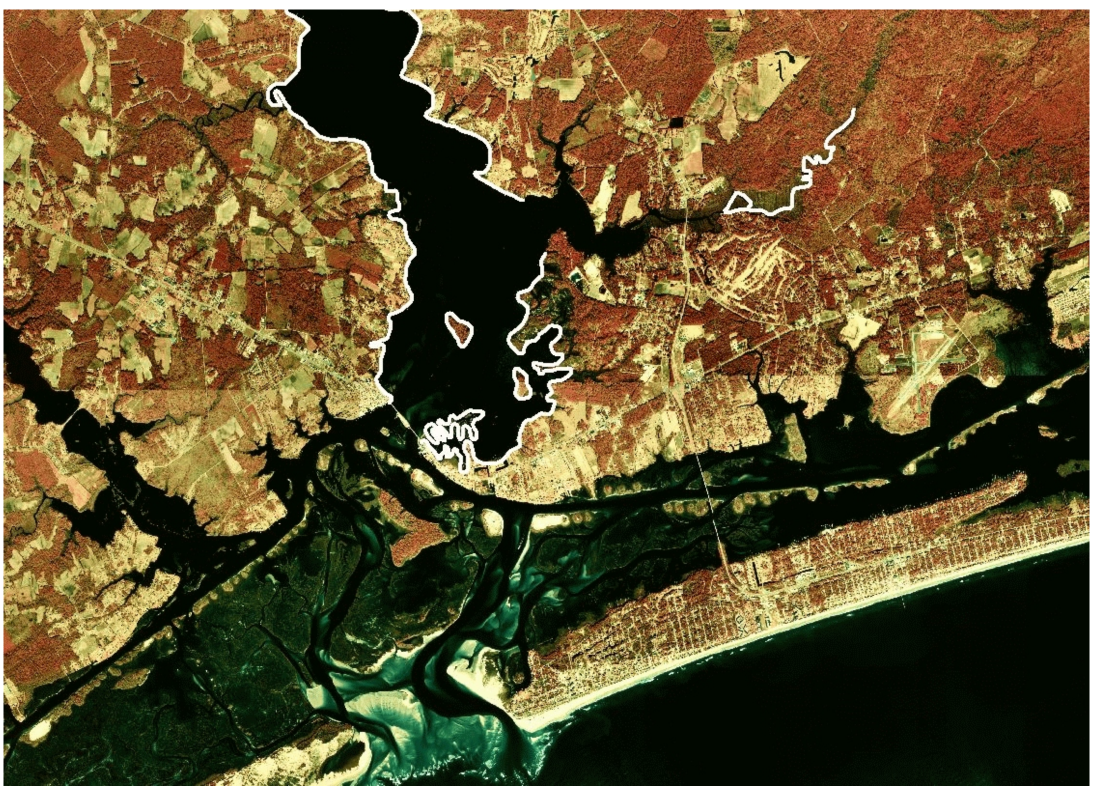


Figure 18. Anadromous fish spawning and rearing areas of the White Oak River are highlighted in white outline. Bogue Inlet is at the lower left of the photograph. Data from NC Division of Marine Fisheries.

The White Oak River that drains into Bogue Inlet contains anadromous fish spawning areas from north of the North Carolina Route 24 bridge to Maysville (Figure 18). Anadromous and catadromous fish that use these areas include alewife (*Alosa psuedoharengus*), striped bass (*Morone saxatilis*), blueback herring (*Alosa aestivalis*), American shad, hickory shad (*Alosa mediocris*), Atlantic sturgeon (*Acipenser oxyrinchus*) and American eel (Dr. J. Hightower, North Carolina State University; C. Waters, NC WRC; and W. Laney, USFWS, personal comm.). Designated fishery nursery areas within the tidal influence of Bogue Inlet include Queens Creek, Parrots Swamp, and Dicks Creek to the northwest and Pettiford Creek to the northeast.

Commercial fishery landings from the White Oak River/Bogue Inlet area average 241,971 lbs harvested and for an annual value of $ 390,900. Up to 39 fishery species have been commercially taken each year from this system. Blue crab, shrimp, hard clams, spot, mullet (*Mugilidae* sp.), and southern flounder are the largest annual catches by weight from the White Oak River and Bogue Inlet (NC DMF, unpublished data).

The tidal shoal system within Bogue Inlet provides spawning habitat for blue crab and red drum. The sheltering effect of the shoals often creates SAV habitat on the lee side of the shoals, but to date no inventories of SAV have been performed in Bogue Inlet. Extensive SAV beds are present in adjacent Bogue Sound, however, indicating the likelihood of the Bogue Inlet complex to contain additional SAV beds. Dudley Island is an example of how the flood tidal shoal system can generate abundant marsh areas in addition to SAV. This marsh complex has been designated a Significant Natural Heritage Area due to its high resource value. Adjacent Huggins Island is now managed by Hammocks Beach State Park and contains high archaeological value as an historic military defense site in coastal North Carolina.

Tidal shoals that are subaerial during low tides are valuable foraging and roosting habitat for migratory shorebirds and colonial waterbirds. Some of these shoals are supratidal even at high tide and provide additional habitat to avian species such as brown pelican (*Pelecanus occidentalis*), cormorants (*Phalacrocorax* sp.), egrets, plovers, black skimmer, American oystercatcher, and numerous gull and tern species. The North Carolina Wildlife Resources Commission (NC WRC) manages several of these supratidal shoals for their avifaunal use, most of which are owned by the state.

In 1998, the Bogue Inlet shoal system encompassed approximately 250 acres (Figure 15). This was the fourth largest intertidal shoal system in the state south of Cape Lookout. Overall, Bogue Inlet provided the eighth largest inlet complex in terms of habitat available to avifauna in 1998 (Appendix D).

The inlet shorelines on both Bogue Banks and Hammocks Beach State Park have consistently supported bird nesting habitat. Black skimmers, least terns, and Wilson's plovers are nesting on bare sandy flats adjacent to the inlet on both shoulders in 2002 (D. Allen, pers. comm.). Piping plovers, common terns, willet and American oystercatcher also have nested in these areas. During migratory periods, piping plover, Wilson's plover, semipalmated plover (*Charadrius semipalmatus*), red knot, sandwich tern (*Sterna sandvicensis*), Forster's tern (*Sterna forsteri*), Royal tern (*Sterna maxima*), least tern, gull-billed tern, common tern, black tern (*Chlidonias* *niger*), Caspian tern (*Sterna caspia*), herons, egrets, marbled godwit (*Limosa fedoa*), laughing gull (*Larus atricilla*), and cormorant are commonly found in and around the inlet. Overwintering bird species include piping plover, brown pelican, cormorants, Forster's tern, Royal tern, dunlin (*Calidris alpina*), and various gull species (Fussell 1985). The Bogue Inlet area also provides overwintering habitat for seabirds and diving ducks, including common loons, red-throated loons (*Gavia stellata*), northern gannets and red-breasted mergansers. Faunal use of the inlet shoreline at The Pointe in Emerald Isle is currently restricted by the presence of several sandbag revetments protecting structures from inlet currents (Figure 19), but the extensive sand spit and marsh areas to the north of The Pointe remain undeveloped and unstabilized.

Bogue Inlet is minimally disturbed by anthropogenic activities. The sandbag revetments at The Pointe have limited migratory bird habitat, but this area of disturbance is spatially limited to less than 1/8 of a mile of shoreline. The western inlet shoreline and the bulk of its interior islets are in conservation status, offsetting the artificial stabilization on the eastern shoreline. The Corps maintains a navigational channel through the inlet, but the channel follows the natural thalweg, or deepwater channel, through the inlet. The Town of Emerald Isle is currently evaluating the feasibility of dredging a new, larger channel to the west of the current thalweg in an effort to realign ebb tidal flows away from development at The Pointe. Material removed from the proposed channel would be used as beach fill along the oceanfront beaches of Emerald Isle under an existing Corps Regulatory permit. Any material leftover from the beach fill will be used to constrict the existing ebb tidal channel along the eastern shoulder of the inlet. If the project receives the approval of the town and regulatory agencies, dredging is proposed for the winter of 2003-04.

Figure 19. Sandbag revetments along the Bogue Inlet shoreline at The Pointe have eliminated natural sandy inlet shoulder habitat for migratory birds. Photo taken May 30, 2002, by USFWS.

Beaufort Inlet

The fish and wildlife resources in and around Beaufort Inlet are as abundant and diverse as those at Bogue Inlet. The same federally-protected species that may be present in the Bogue Inlet area during various seasons are likely to use Beaufort Inlet as well.

The Beaufort Inlet area has been designated with numerous management characterizations reflecting its high resource value. The Natural Heritage Program has delineated several Significant Natural Heritage Areas within the project area, including the Rachel Carson National Estuarine Research Reserve (NERR) to the northeast and Shackleford Banks to the east (Figure 1). Tidal inlets have also been designated as HAPC for red drum, penaeid shrimp and the snapper-grouper complex by the SAFMC. The Service has designated critical habitat for overwintering piping plovers at the Rachel Carson NERR and Shackleford Banks. Shackleford Banks forms the southernmost portion of Cape Lookout National Seashore and has also been designated a Wilderness Area. The United States Congress has designated Fort Macon State Park and portions of Beaufort Inlet as OPA NC-04P and L03AP respectively under the Coastal Barrier Resources Act, coincident with the boundaries of the NERR and Cape Lookout National Seashore.

The Newport River that drains into Beaufort Inlet contains anadromous fish spawning areas upriver from Morehead City. Designated fishery nursery areas within the tidal influence of Beaufort Inlet include Calico Creek, Crab Point Bay, the Newport River, Harlow Creek, Oyster Creek, Bell Creek, Eastman Creek, Ware Creek, and Russell Creek. Within the North River estuary to the northeast, fishery nursery areas have been delineated in the North River, Turner Creek, Ward Creek, North and South Leopard Creeks, and Whitehurst Creek. The inlet also provides a passageway for fish eggs and larvae to move from offshore spawning areas into estuarine nursery areas. Research conducted by scientists at the National Oceanic and Atmospheric Administration (NOAA) in Beaufort have documented 129 different species of larval fish in and around Beaufort Inlet to date, finding larvae present during every month of the year.

Commercial fishery landings from the Newport River/Beaufort Inlet area is a million dollar industry, with an average of 683,550 lbs for an annual value of $ 1,065,455 from 1994 to 2001 (Table 10). Over two dozen fishery species have been commercially harvested each year from this system. Blue crab, shrimp, hard clams, Eastern oyster (*Crassostrea virginica*), mullet, and southern flounder are the largest annual catches by weight from the Newport River and Beaufort Inlet area (NC DMF, unpublished data).

The tidal shoal system within Beaufort Inlet provides spawning habitat for blue crab and red drum. The Rachel Carson NERR is an example of how the flood tidal shoal system can generate abundant marsh and bare sand areas in addition to SAV. This marsh and island complex has been designated a Significant Natural Heritage Area due to its high resource value. Adjacent Fort Macon State Park is now managed by the state and contains high archaeological value as an historic military defense site in coastal North Carolina. Beaufort Inlet has more recently received scientific attention as a shipwreck believed to be Blackbeard's *Queen Anne's Revenge* has been

Table 10. Commercial fisheries landings from the Newport River and Beaufort Inlet, 1994 to 2001. Data are provided by the North Carolina Division of Marine Fisheries and represented in state fiscal years (July 1 through June 30).

Year	Average Landings (lbs)	Average Value
1994	665,967	$ 842,699
1995	719,646	$ 1,106,498
1996	595,451	$ 1,043,672
1997	797,723	$ 1,331,542
1998	671,065	$ 986,170
1999	831,429	$ 1,202,862
2000	615,374	$ 936,470
2001	571,743	$ 1,073,728
1994-2001 Average	**683,550**	**$1,065,455**

discovered on the southwestern portion of the inlet's ebb tidal delta. Other shipwrecks adjacent to Beaufort Inlet are currently being investigated for archaeological significance and recovery.

Tidal shoals that are subaerial during low tides are valuable foraging and roosting habitat for migratory shorebirds and colonial waterbirds. Some of these shoals are supratidal even at high tide and provide additional habitat to numerous species of shorebirds and colonial waterbirds species. In 1998, the Beaufort Inlet system encompassed approximately 463 acres of shoals and inlet shoulders available to shorebirds and colonial waterbirds (Figure 20). This was the fifth largest flood tidal shoal system in North Carolina with only Cape Fear River, New Drum, Oregon, and Ocracoke Inlets exceeding it. Overall, Beaufort Inlet provided the sixth largest inlet complex in North Carolina in terms of habitat available to migratory shorebirds and waterbirds in 1998.

The inlet shorelines on both Beaufort Inlet and Shackleford Banks have supported bird nesting habitat for black skimmer, common tern, Gull-billed tern and least tern (NC WRC, unpublished data). During migratory periods, thousands of birds are commonly found in and around the inlet. Birds commonly seen in Beaufort Inlet during the winter months include common loon, double-crested cormorants (*Phalacrocorax auritus*), red-breasted mergansers, northern gannets, Bonaparte's gulls (*Larus philadelphia*), Great blue heron (*Ardea herodias*) and Black-crowned night-herons (*Nycticorax nycticorax*). Willets, ruddy turnstone (*Arenaria interpres*), sanderlings and various gull species are often found along the beaches of Fort Macon State Park during the winter. Avian use of the inlet shoreline at Fort Macon State Park can attract birds not regularly seen at North Carolina inlets (e.g., purple sandpiper (*Calidris maritima*), scoters, eiders, ducks) because of the several groins and jetty (Figure 21) (Fussell 1985).

Figure 20. A 1998 aerial photograph of Beaufort Inlet shows Fort Macon and Brandt Island to the left, Shackleford Banks to the right, and the Rachel Carson NERR to the upper right seaward of the Town of Beaufort. Photo courtesy of US Geological Survey.

Figure 21. Fort Macon State Park at Beaufort Inlet has several groins (foreground) and a rubble mound jetty (background) stabilizing its inlet shoreline. Photo taken May 29, 2002, by USFWS.

The western side of Beaufort Inlet supports willets, ruddy turnstone, black-bellied plover (*Pluvialis squatarola*), sanderlings, gulls and terns most commonly during the summer. Spring and fall migratory periods bring red knot, whimbrel (*Numenius phaeopus*), Western sandpiper (*Calidris mauri*), scoters, common loon, red-throated loon, heron, egret, and White ibis (*Eudocimus albus*) (Fussell 1985). Gull-billed terns, black skimmers and terns have nested in the past at Beaufort Inlet.

Within the inlet itself, Radio Island and the Rachel Carson NERR both generate diverse birdwatching. At the south end of Radio Island, Fussell (1985) recommends looking for common loon, brown pelican, double-crested cormorant, red-breasted merganser, gulls, terns, ruddy turnstone, sanderlings, American oystercatcher, purple sandpiper, and various seabirds following storms. At the Rachel Carson NERR, which Fussell (1985) refers to as the Bird Shoal Complex for its avian diversity, common shorebird species include American oystercatcher, semipalmated plover, ruddy turnstone, willet, whimbrel, Greater yellowlegs, Short-billed dowitcher, Marbled godwit, dunlin, red knot, Long-billed curlew (*Numenius americanus*), Western sandpiper, semipalmated sandpiper, sanderling, piping plover, black-bellied plover, and Wilson's plover. Waterbirds regularly seen at the Rachel Carson NERR are black tern, common tern, sandwich tern, black skimmer, cormorant, Glaucous gull, Iceland gull, Lesser Black-backed gull, Bonaparte's gull, Little gull, brown pelican, Black-crowned night-heron, and White ibis (Fussell 1985).

Beaufort Inlet is one of the most managed in North Carolina (see Appendix F). Both inlet shorelines have historically functional jetties and groins. The jetty on Shackleford Banks is currently landlocked as the inlet migrated to the west in the last 50 years (Moslow and Heron 1994). The State Port at Morehead City has required a navigational channel approximately 45 feet deep through the Newport River estuary and Beaufort Inlet. The beaches along Fort Macon State Park periodically receive dredged material disposal from maintenance dredging of the navigation channels, most recently during the early spring of 2002. The U.S. Coast Guard has a base on the north side of Fort Macon State Park; the shoreline of this base is stabilized with riprap, groins and bulkheads. Interior islands have been created by dredged material and/or artificially stabilized. The mainland shoreline at the State Port is entirely bulkheaded, and large portions of Radio Island are stabilized. The northwestern shorelines adjacent to Beaufort Inlet are heavily industrialized while the northeastern shorelines along the Highway 70 causeway and Beaufort waterfront are filled with marinas and associated bulkheads.

Nearshore and Offshore Marine Ecosystems

The marine environments found offshore North Carolina's barrier islands, including hardbottoms, have been previously described in USFWS (1999), USFWS (2000a), USFWS (2000b) and USFWS (2002a), which are incorporated by reference here. The Cape Lookout area is more diverse than most marine areas along the U.S. Atlantic coast due to the mixing of the Gulf Stream from the south with the Labrador Current from the north. As a result of this oceanographic mixing, the marine flora and fauna are a mixture of cold-water and warm-water species. Highly migratory aquatic species such as whales and recreationally important finfish are common. Seabirds from the Arctic and the tropics co-mingle, with the unique east-west orientation of Bogue and Shackleford Banks often providing the first or last landfall for north-south migrating birds.

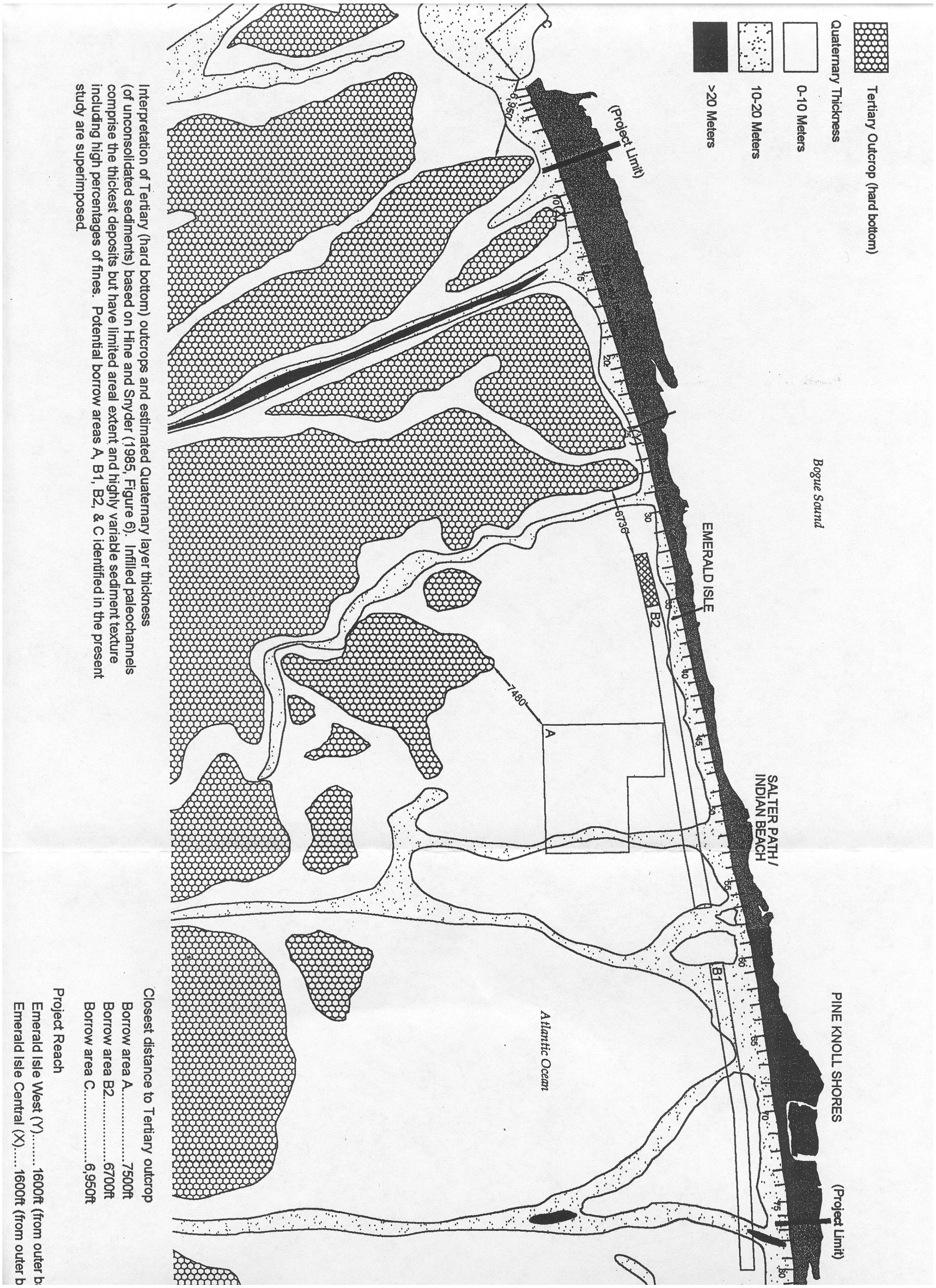
Bogue Banks serves as a transitional marine environment in another way as well – the seafloor offshore is dominated by hardbottoms to the west and softer sediment substrates to the east. Several studies have documented the hardbottom areas offshore (e.g., Hine and Snyder 1985; Mallette 1986; Steele 1986) and Figure 22 reproduces the distribution map of Hine and Snyder (1985) as included in CSE and Stroud (2000). The hardbottoms approach the beaches of Bogue Banks fairly closely, as evidenced by the fairly regular occurrence of coral and other encrusting organisms washing up on the beaches of the island (Figure 23).

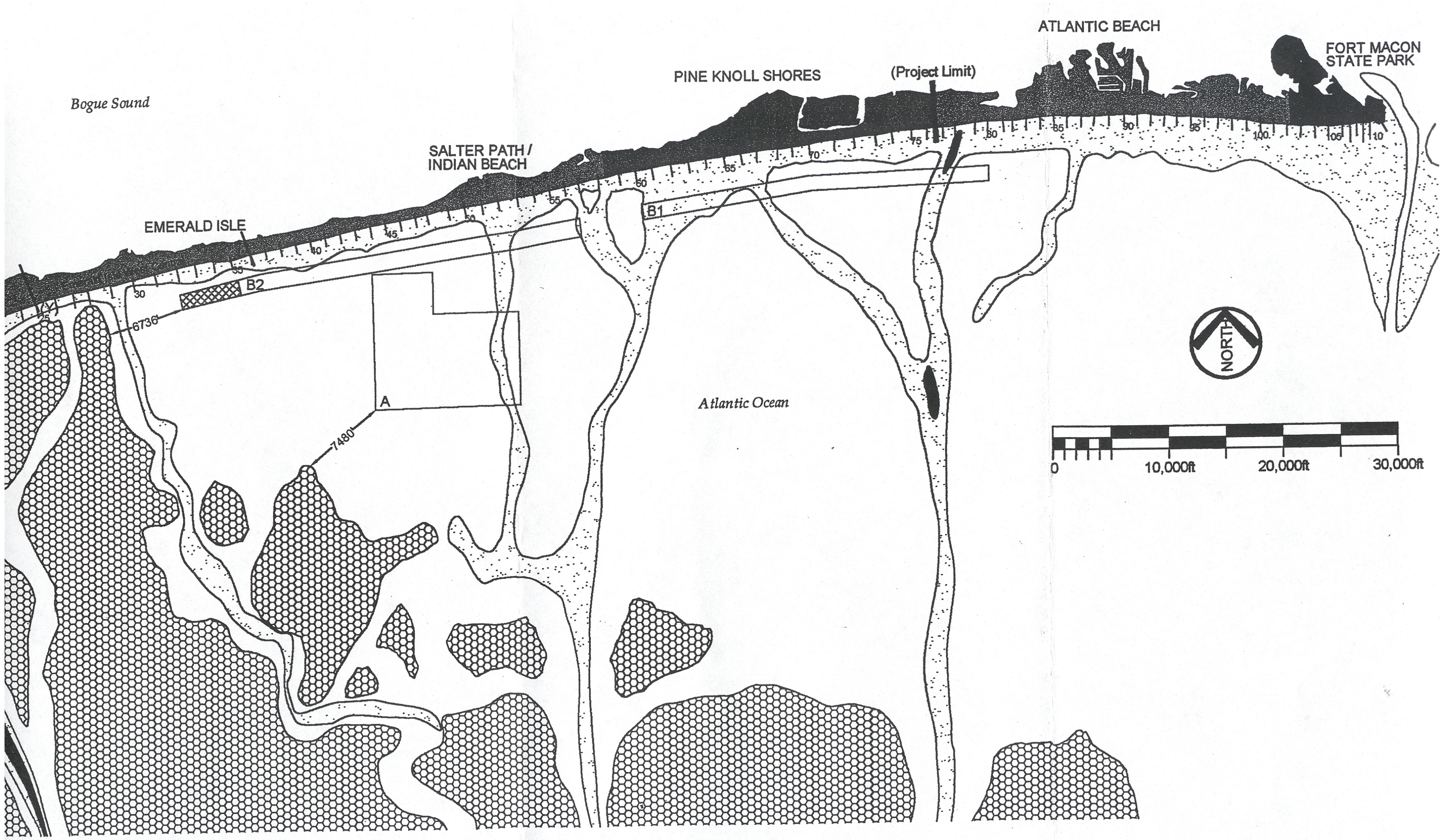
The marine seafloor also supports numerous artificial reefs in varying states of stability (i.e., Artificial Reefs 315, 320, 330, 340, 342, and 345). Roughly two decades ago the state used discarded tires to construct some of these reefs. The metal chain fastening the tires together has subsequently corroded and the tires have washed up on the beaches of Bogue Banks following recent hurricanes. The local beach fill project also uncovered over 4000 of the tires in the three offshore dredge sites. Countless shipwrecks are found offshore Bogue and Shackleford Banks, ranging from World War II military vessels to 19th and early 20th century passenger transport and Colonial vessels.

The dredges for the recent local beach fill project also encountered five federally-protected sea turtles in their offshore dredge sites, killing four and injuring one. The turtles were encountered during December and April, indicating the high productivity of the marine area offshore Bogue Banks when waters exceed approximately 58 degrees Fahrenheit.

Recreational and commercial fishing is a multimillion dollar industry in the offshore project area. Several fishing tournaments are held each year targeting specific species such as blue marlin (*Makaira nigricans*), yellowfin tuna (*Thunnus albacares*), wahoo (*Acanthocybium solanderi*), dolphin (*Corypaena hippurus*) and king mackerel (*Scomberomorus cavalla*). Table 11 lists the annual catch and value of commercial fisheries landed in Carteret County that were harvested within 3 miles of shore from Cape Hatteras south to the South Carolina boundary. Table 12 lists the same data for catches from federal waters (those greater than 3 miles offshore). Over 140 different fishery resources are harvested from the nearshore and offshore waters. Fishery landings made in Carteret County are presumed to require travel through the proposed project area.

Figure 22. Extensive areas of hardbottom occur offshore Bogue Banks, as reproduced from Hine and Snyder (1985) from CSE and Stroud (2000). Figure 22a shows the hardbottom areas off of the western portion of the island and Figure 22b the eastern portion of the island.





d estimated Quaternary layer thickness
Snyder (1985, Figure 6). Infilled paleochannels
al extent and highly variable sediment texture
ow areas A, B1, B2, & C identified in the present

Closest distance to Tertiary outcrop

Borrow area A..................7500ft
Borrow area B2.................6700ft
Borrow area C..................6,950ft

Project Reach

Emerald Isle West (Y)........1600ft (from outer bar)
Emerald Isle Central (X).....1600ft (from outer bar)

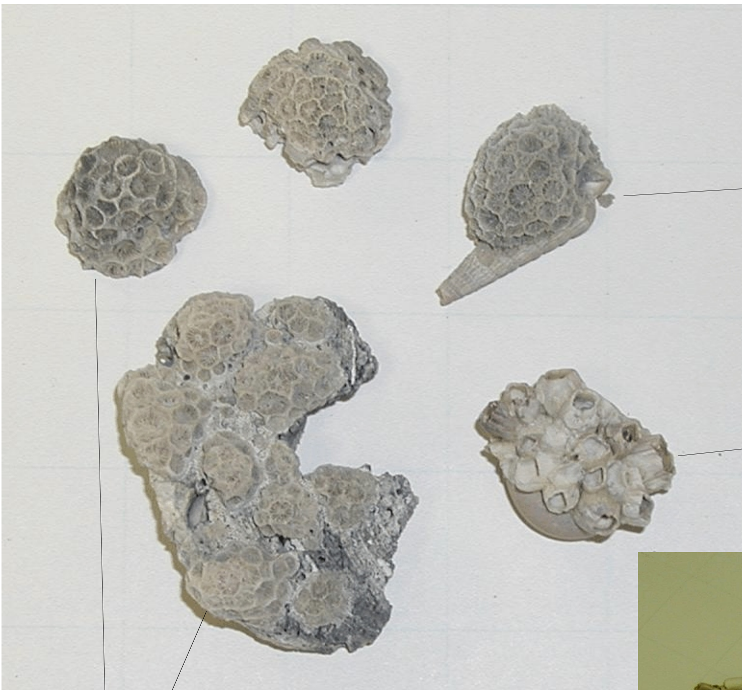
Table 11. Commercial fisheries landings made in Carteret County from the nearshore and offshore marine area south of Cape Hatteras to the South Carolina border and within 3 miles of shore, 1994 to 2001. Data are provided by the North Carolina Division of Marine Fisheries and represented in state fiscal years (July 1 through June 30).

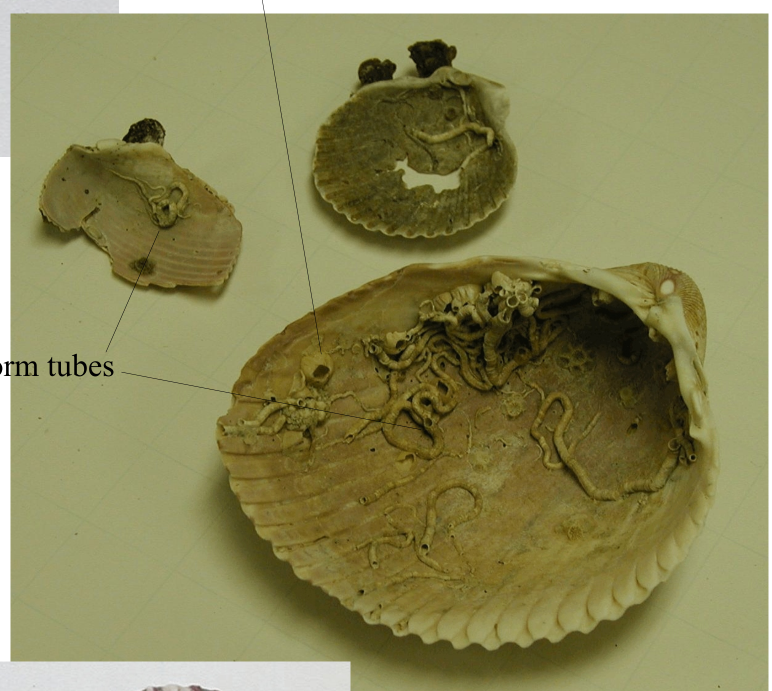
Year	Landings (lbs)	Estimated Value
1994	77,035,013.63	$ 4,164,463.69
1995	63,799,951.89	$ 5,446,336.66
1996	62,658,021.46	$ 7,929,216.92
1997	109,609,244.82	$ 11,411,581.18
1998	64,110,110.50	$ 6,591,962.75
1999	42,211,465.60	$ 4,591,076.12
2000	55,081,596.57	$ 4,749,465.24
2001	54,680,854.74	$ 5,239,279.55
1994-2001 Average	**66,148,282.40**	**$ 6,265,422.76**

Table 12. Commercial fisheries landings made in Carteret County from the nearshore and offshore marine area south of Cape Hatteras to the South Carolina border and greater than 3 miles from shore, 1994 to 2001. Data are provided by the North Carolina Division of Marine Fisheries and represented in state fiscal years (July 1 through June 30).

Year	Landings (lbs)	Estimated Value
1994	3,441,498.14	$ 4,017,915.52
1995	4,878,202.04	$ 6,343,473.36
1996	3,215,636.19	$ 4,011,477.72
1997	5,938,877.00	$ 4,219,268.25
1998	4,498,620.20	$ 4,336,147.01
1999	4,359,971.35	$ 3,839,928.59
2000	4,686,378.69	$ 4,471,756.95
2001	3,061,194.26	$ 3,761,611.99
1994-2001 Average	**4,260,047.23**	**$ 4,375,197.42**

Figure 23. Coral, encrusting and boring (endolithic) fauna are often found along the beaches of Bogue Banks, indicating the presence of hardbottoms in the nearshore and offshore. Hardbottoms are the preferred habitat for creatures requiring rock outcrops or similar hard substrates to attach to, grow over or bore into. These fauna also may attach to exposed shells, as shown below. The presence of encrusted shells indicates the presence of these fauna in the nearshore and offshore waters of the project area. The pale blue lines in each photo are one inch apart for scale.





Numerous captains offer half and full day recreational charters offshore to catch various species of fish, watch seabirds or marine mammals, dive shipwrecks or reefs, or experience "mystery tours" revolving around the human history offshore Bogue and Shackleford Banks. Half-day charters for deep sea fishing range from $ 40 - 50 per adult. Full-day charters range from $ 60 - 65 per adult. Private charters of 49 to 80 adults cost $ 3000 - 5000 depending on the season and day of the week. Smaller private charter boats (6 adults or less) cost $ 650 - 1350 for full-day and $ 300 - 500 for half-day deep water cruises. Boat rentals for nearshore and sound cruises are also available for $ 250 to 400 per day.

Dolphin watching cruises extolling "beautiful views of salt marsh, wildlife and beautiful homes" are advertised for $250 for 1.5 to 2 hours. Others advertise birding, sightseeing, nature photography and shell collecting for $400 a day.

Some local dive companies advertise that "North Carolina is without a doubt the premier dive destination on the entire East Coast." The marine waters offshore Bogue and Shackleford Banks are described as "warm, clear waters ... with visibility of up to 200 feet", implying their dependence on the water quality of the offshore marine area for their business. Snorkeling and scuba trips, including instruction, cost $175 per person. Trips list tropical fish, soft corals, moray eels, lobsters, sea turtles, large game fish and sharks as attractions.

Besides the extensive hardbottoms in the offshore marine area, there are two known sand bodies. The offshore project area contains the Offshore Dredged Material Disposal Site (ODMDS) for dredge spoils from maintenance dredging of navigational channels and the experimental nearshore disposal site offshore eastern Atlantic Beach. Biological resources in these two areas is are not readily known. A third area with almost unlimited supplies of sand are the Cape Lookout shoals. These natural shoals have been designated as an HAPC by the SAFMC for their very high aquatic resource value.

SECTION 6. FUTURE FISH AND WILDLIFE RESOURCES WITHOUT PROJECT

The Service has previously summarized the anticipated impacts of previously authorized artificial beach and dune construction projects in USFWS (1999), USFWS (2000a), USFWS (2000b), USFWS (2001) and USFWS (2002a). These reports are incorporated by reference.

Resource category determinations, with supporting technical information, for each of the habitat complexes described in Section 5 are presented below. These determinations serve as one way to evaluate the existing fish and wildlife resource values in the project area. Alterations to those determinations, if any, will be discussed in light of reasonably foreseeable, future coastal projects in the Bogue Banks Shore Protection Project study area. Appendix D summarizes the relative importance of the Bogue and Beaufort Inlet areas to migratory birds in North Carolina, and Appendix F ranks the level of past and present disturbance at tidal inlets between Cape Henry, Virginia and Cape Romain, South Carolina.

Resource Category Determinations

The Bogue Banks Shore Protection Project study area can be divided into eight distinct areas of similar ecology (as outlined in Section 5): (1) Bogue Banks interior; (2) Bogue Banks oceanfront shoreline; (3) Bogue Banks estuarine shoreline; (4) Bogue Sound; (5) Bogue Inlet; (6) Beaufort Inlet; (7) nearshore marine; and (8) offshore marine. Each of these regions supports a different assemblage of fish and wildlife resources, varying degrees of human disturbance, and clear geographic boundaries. The relative value of each of these regions to fish and wildlife resources can be ranked, as outlined in Section 4. The Service assessed the value of each of the eight geographic areas to fish and wildlife resources in coordination with the NC WRC, NC DMF, NMFS and the Wilmington District of the Corps. The resource categories discussed in this section represent a consensus amongst these agencies.

Sixty-four evaluation species were selected for these regions (Tables 2 to 5). Each species was selected based upon its known occurrence in the project area, utilization of the regions by different life history stages, seasonal abundance, and ecological niche. Tables 2 to 5 list each species, its ecological niche, population status and management status (if known). The areas where each species occurs within the project area are listed in Table 1.

Twenty different species of aquatic resources were selected to reflect the freshwater, estuarine and marine habitats found in the project area. These species represent benthic and pelagic species, various positions in the food web, and several life history stages. The fishes include representative anadromous and catadromous species. Some of the fish are bottom feeders while others are pelagic predators. The bottlenose dolphin was selected as the representative marine mammal since the majority of marine mammals found in the project area are Federally-listed threatened and endangered species, which cannot be evaluation species. Horseshoe crabs are important bioturbators, nest on estuarine beaches and provide an important source of nourishment for avifauna via their eggs (Jackson 2001; Smith et al. 2002).

The twenty-four species of avifauna selected as evaluation species represent diving, wading, swimming, and terrestrial birds. Some species feed upon intertidal invertebrates, while others feed on fish, crustaceans, insect larvae or seeds and berries. Several of the evaluation species utilize the project area for nesting, while others for migratory staging or overwintering. Birds that are only occasional or accidental species to the project area were not considered sufficient for further evaluation, as they do not depend on the project area for sustenance or reproduction. The piping plover is not included, nor is its critical habitat, due to its protection status under the federal Endangered Species Act. Species that may be state-listed or Federal Species of Concern were included, however, because they do not have the same level of federal protection.

The avian species range from those with no significant concern (or are common) to those with extremely high management concern for the nation and regionally. American oystercatchers and red knots, for instance, are two of the four top priority species for the region. North Carolina provides valuable nesting habitat for American oystercatchers and Wilson's plovers, for which there are an estimated 1000 and 1500 nesting pairs respectively on the entire Atlantic and Gulf coasts combined (Hunter 2001). The state also provides migratory and overwintering habitat for the oystercatcher, increasing its importance to the species. Based upon their high priority status and known use of the project area, these species were included as evaluation species.

Sanderlings are considered an evaluation species due to their high concentrations in North Carolina during winter periods, and their tendency to forage on oceanfront beaches the majority of the time (Hunter 2001, Root 1988). Willets are a shorebird found year-round in North Carolina, and dunlin represent a migratory shorebird that feeds in a wider variety of habitats than sanderlings. Eastern painted buntings, boat-tailed grackles and marsh wrens were included to represent terrestrial and marsh habitats. Similarly, northern gannet, red phalarope and Cory's shearwater were chosen to represent seabirds present in the nearshore and offshore project area. Several species of colonial waterbirds are included as evaluation species to represent bare ground, scrub-shrub and forest nesting areas, as well as different seasons of high use and varying foraging techniques and sources. Finally, black rails, common loons, red-breasted mergansers and canvasbacks were included to represent waterfowl that are found in the project area.

The remaining evaluation species are vegetation and invertebrate species. The vegetation represents key habitat types – the eelgrass and widgeon grass representing SAV and *Spartina* spp. the estuarine marsh, for instance. Live oak was selected to represent the maritime forest habitat, red bay to represent scrub-shrub wetlands and Atlantic white cedar to represent swamp forest. Sea oats were selected as the representative vegetation for the oceanfront dunes. *Sargassum* is the evaluation species for macroalgae found growing attached to hardbottom areas or areas with limited sediment cover; this marine plant provides additional habitat value, especially for marine birds and fish, when free-floating.

The invertebrates included as evaluation species represent the benthic ecological niche of the intertidal beach (coquina clams, mole crabs), estuarine benthos (Eastern oyster, hard clam, bay scallop), nearshore or offshore seafloor (sand dollar, moon snail). Mole crabs, coquina clams and ghost crabs represent the macroinvertebrates commonly found on the beach and intertidal oceanfront shoreline. Each of these three species has been used as indicator species in previous monitoring projects in the project area (e.g., Lindquist and Manning 2001, Peterson et al. 2000, Reilly and Bellis 1978).

The sand dollar was chosen as a representative of the phylum Echinodermata and because it was used as an indicator species in the large scale monitoring project in New Jersey (Ray 2001, Wilber 2001). The bay scallop was chosen as the representative mollusk for SAV areas. The polychaete worm *Scolelepsis squamata* represents the burrowing segmented worms that are an important food source for birds and fish in the intertidal, nearshore and offshore areas. The encrusting star coral and boring bivalve *Jouanettia quillingi* were chosen to represent the epifauna found in marine hardbottom areas.

Gastropods are represented by the moon snail for the nearshore and offshore areas and by the marsh periwinkle for the estuarine area. Eastern oyster was selected for its importance as a filter feeder, a keystone species for estuarine reef-like structures, and commercial value. Hard clams were chosen for their economic significance and occurrence in sandy and vegetated estuarine substrates. Bay scallops are commonly found in eelgrass beds, and are more mobile and shorter lived than hard clams and oysters.

The resource category determination for each of the eight ecological regions within the project area are presented in Table 13, and the discussion for each determination follows.

Table 13. Resource category determinations, or the value of the existing habitats to fish and wildlife, were calculated for eight distinct regions within the project area.

Area	Resource Category	Value to Fish and Wildlife
Bogue Banks Interior	2	High value, relatively scarce
Bogue Banks Oceanfront Shoreline	4	Medium to low value
Bogue Banks Estuarine Shoreline	2	High value, relatively scarce
Bogue Sound	2	High value, relatively scarce
Bogue Inlet	2	High value, relatively scarce
Beaufort Inlet	3	High to medium value, relatively abundant
Nearshore (0 to 30 ft water depth)	2	High value, relatively scarce
Offshore (greater than 30 ft water)	2	High value, relatively scarce

I. *Bogue Banks Interior*

The terrestrial habitats on Bogue Banks represent some of the last remaining tracts of maritime forest and freshwater wetlands on barrier islands in coastal North Carolina. The unusual height and width of the island, along with its geographic orientation, further creates a comparably unique ecological setting. At least 1,015 acres of maritime forest are estimated to be in conservation status on the island, with significant tracts at Fort Macon State Park, the Theodore Roosevelt State Natural Area and the Hoop Pole Creek preserve owned by the NCCF. Approximately 2,000 acres of freshwater and brackish wetlands are estimated on the island. Most of these wetlands are scrub-shrub and emergent marsh, but roughly 166 acres are forested wetlands.

Evaluation species for this area include live oak, red bay, Atlantic white cedar, Eastern painted bunting, and boat-tailed grackles. The island's interior provides shelter and foraging opportunities for numerous migratory birds, mammals, reptiles and other wildlife. With the exception of a few areas near Nags Head and Buxton on the Outer Banks, Bogue Banks contains more maritime forest and freshwater wetland habitat than any other barrier island in North Carolina. As coastal development continues to increase, these habitats remain threatened with fragmentation and elimination. Therefore Bogue Banks' interior is a resource category 2 area, of high value to the evaluation species. This high value may decrease in the future with continued development that clears and further fragments the freshwater wetland and maritime forest ecosystems.

II. *Bogue Banks Oceanfront Shoreline*

The oceanfacing shoreline of Bogue Banks has been increasingly manipulated in recent years. Individual property owners and local government entities have used beach scraping (bulldozing), sand fencing, sandbag revetments and dredge and fill projects to stabilize the shoreline. Beach driving and lighting pose potential hazards to nesting wildlife. Existing federal dredge disposal projects with beach placement include Fort Macon, Atlantic Beach, Pine Knoll Shores and Emerald Isle. The towns of Pine Knoll Shores, Indian Beach and Emerald Isle currently have federal and state permits to construct a large dredge and fill project along 17 miles of oceanfront beach. The first phase of this project was constructed along ~6 miles of beachfront during the winter of 2001-02.

Evaluation species for the Bogue Banks' oceanfront shoreline include coquina clams, mole crabs, ghost crabs, a polychaete worm, horseshoe crabs, least terns, common terns, black skimmers, dunlins, sanderlings, short-billed dowitchers, willets, Wilson's plovers, red knots, American oystercatchers, Gulf kingfish and Florida pompano. Most of the avian evaluation species are declining and have been designated as high or moderate priority species for management. Studies following beach scraping and fill activities (e.g., Lindquist and Manning 2001, Peterson et al. 2000, Reilly and Bellis 1978) have documented the decline of coquina clams and mole crabs with each event. No waterbird or shorebird nesting has been observed on the oceanfront beaches in many years.

Due to the high management priority for the majority of the evaluation species and the degraded habitat quality of the oceanfront beaches, this habitat has a resource category of 4, or of medium to low value for the evaluation species.

III. *Bogue Banks Estuarine Shoreline*

The estuarine shoreline of Bogue Banks, on the north side of the island, consists of fringing marsh (~51%), sandy beach (~7%), artificially stabilized (~22%) and a mix of stabilized and natural shorelines (~20%). In some areas scrub-shrub estuarine wetlands border the Bogue Sound shoreline. One area, at Archer Creek, has been designated a primary nursery area. Other areas such as Hoop Pole Creek and the Theodore Roosevelt State Nature Preserve contain segments of estuarine shoreline that have been placed in conservation status. The Roosevelt tract has also been designated an Otherwise Protected Area (OPA) under the Coastal Barrier Resources Act (CBRA). The only significant manipulation to the natural configuration of the Bogue Banks estuarine shoreline is a large dredged material island at the east end, Brandt Island.

Evaluation species for this area include little blue heron, snowy egret, marsh wren, common loon, black rail, canvasback, red-breasted merganser, *Spartina* spp., horseshoe crab, marsh periwinkle, Eastern oyster, hard clam, shrimp, blue crab, diamondback terrapin, Atlantic croaker, striped mullet, menhaden, hogchoker, American eel, American shad, spot, red drum, and southern flounder. Many of the aquatic evaluation species utilize the estuarine shoreline areas during juvenile development as nursery habitat. The adult stages of several are commercially and recreationally valuable fisheries. The avifauna use the estuarine shoreline habitats for foraging, nesting and shelter during stormy weather. Nationally and regionally, undisturbed estuarine shoreline habitats are declining.

Due to its high ecological use and declining abundance, the Service determined that the estuarine shoreline of Bogue Banks is a resource category 2 (high value). If current trends of estuarine wetland loss continue, this value may decline in the future as the estuarine shoreline becomes dominantly stabilized and natural marsh and sandy beach shorelines are increasingly fragmented.

IV. *Bogue Sound*

Bogue Sound has been designated a Habitat Area of Particular Concern (HAPC) by the South Atlantic Fishery Management Council, a geographic designation reflecting its high value to aquatic resources. The distribution of seagrasses within the sound is estimated at over 6100 acres, consisting of a mix of widgeongrass, eelgrass and shoalgrass (*Halodule wrightii*). The western portion of the sound is designated as an ORW, the highest in the state's ranking system for water quality. The east-west orientation of the sound and its intermediate width (i.e., narrower than Pamlico Sound, wider than Middle Sound) render it one of a only two-of-a-kind in North Carolina (Back Sound being the other with the same geographic features).

Brackish marsh (over 800 acres), intertidal shoals and disposal islands provide habitat to migratory shorebirds and colonial waterbirds that is declining in North Carolina as more dredge and fill projects are constructed. The commercial fishery harvest in Bogue Sound includes 26 species for an average annual value of $ 672,512. Tributaries to the sound contain four designated primary nursery areas for fishery resources (Archer Creek, Goose Creek, Broad Creek and Gales Creek). The variety of salinity concentrations in Bogue Sound create the microhabitats needed by larval and juvenile aquatic resources, fostering their development through various life history stages.

The east-west orientation of the sound creates a comparably unique setting where migratory birds find Bogue Banks and its estuarine system as the first or last estuary and land during long north-south migrations. Diving ducks, waterbirds and shorebirds utilize the sound as a migratory stopover site, with several remaining to overwinter in Bogue Sound and its associated habitats. In addition, Bogue Sound has provided nesting habitat for 14 species of colonial waterbirds, several of which are evaluation species (little blue heron, snowy egret, black skimmer, common tern, least tern, gull-billed tern). Many of the islands used by these birds for nesting have been designated a Significant Natural Heritage Area by the North Carolina Natural Heritage Program. The majority of these species have been designated as high or moderate priority management species due to recent population declines.

Therefore Bogue Sound has a high to medium habitat value, is a limited resource nationally, and has been designated as a geographically important fishery area on a regional basis. The sound also contains several habitat types that should receive special consideration. These areas include mud and sand flats, SAV, wetlands, special aquatic sites and floodplains. Thus its resource category is a 2, a high value. The high value of Bogue Sound is not likely to decline in the future unless the water body is targeted as a sand source for beach fill projects.

V. *Bogue Inlet*

Bogue Inlet has one of the largest tidal shoal systems in North Carolina, providing foraging and loafing habitat for dozens of species of shorebirds and waterbirds. The NC WRC manages some of the emergent shoals as nesting waterbird sites. The barrier island shoulders of the inlet also provide nesting, migratory and overwintering habitat for migratory birds. The shoals provide habitat for spawning red drum and blue crab, both of which are evaluation species for this area. Tidal inlets have been designated a HAPC for red drum, shrimp and the snapper-grouper complex of fish. The North Carolina Natural Heritage Program has designated several areas within or near the Bogue Inlet complex as Significant Natural Heritage Areas for the state. Hammocks Beach State Park on the western shoulder of the inlet is an OPA under CBRA. Some of the small islands within the inlet complex also have cultural resources of historical significance. Altogether, the inlet complex contains sandy shoals, marsh, SAV, and open water habitats.

The White Oak River that drains through Bogue Inlet supports valuable aquatic habitat for spawning anadromous fish like American shad and the catadromous American eel. Bogue Inlet serves as an essential linkage between marine, estuarine and freshwater spawning and nursery habitats for these migratory fisheries. The White Oak River-Bogue Inlet system supports commercial fishery landings for up to 39 species, averaging $390,900 a year in annual revenue for local fishermen.

Bogue Inlet is minimally disturbed at present, with a federal navigational channel maintained within the natural deep channel in the inlet. Some property owners on Emerald Isle have constructed sandbag revetments along the eastern shoreline of the inlet. A proposal to dredge a large channel through the center of the inlet to protect these properties is currently under development, however. Bogue Inlet's current status as one of the least disturbed in the state increases its value to fish and wildlife resources, combined with its various state management designations, generate a high value resource category determination of 2. If the Town of Emerald Isle implements an ebb channel relocation project, the high ecological value of the inlet may be degraded as the inlet becomes more disturbed and this resource category determination will need to be re-evaluated.

VI. *Beaufort Inlet*

Beaufort Inlet is one of the most managed inlets within North Carolina, with hard stabilization on both shoulders (albeit landlocked on the eastern shoulder) and a deep navigational channel to the state port in Morehead City. The barrier island shorelines on both the east (Shackleford Banks) and west (Fort Macon) have been designated as OPAs under the CBRA; the former is part of the Cape Lookout National Seashore and the latter a state park. The Rachel Carson National Estuarine Research Reserve (NERR) is northeast of the inlet, within its tidal influence; this reserve is another OPA and a Significant Natural Heritage Area for the state of North Carolina. The Newport River supports anadromous fish spawning areas and primary nursery areas upriver from Morehead City and Beaufort, again creating an essential linkage between freshwater, estuarine and marine aquatic habitats at Beaufort Inlet.

Over two dozen species of birds have been observed in the Beaufort Inlet area, with greater numbers and diversity at the Rachel Carson NERR. Intertidal shoals and flats within the NERR provide valuable foraging habitat for the migratory shorebirds, waterbirds and waterfowl on the evaluations species list. Over 100 different species of larval fish have been documented within Beaufort Inlet and its surrounding waters.

Beaufort Inlet itself is artificially maintained with a dredged channel exceeding 45 feet of water depth. Maintenance dredging of this channel often deposits dredged material on the Fort Macon shoreline adjacent to the inlet. The inlet and its associated river (the Newport) are more intensively harvested for fishery resources than Bogue Inlet, earning almost triple the amount of annual revenues. Ballast water releases and intakes within the deep navigation channels of the inlet complex have the potential to degrade aquatic habitats by introducing non-native species, contaminants and pathogens.

The highly manipulated state of the Beaufort Inlet complex reduces its ecological value as compared to similar, undisturbed systems. The presence of hard stabilization, dredge disposal on adjacent shorelines and a deepwater navigational channel would suggest a low value to fish and wildlife resources. But one of the jetties is landlocked and non-functional at present, and three valuable conservation tracts (Rachel Carson NERR, Cape Lookout National Seashore, and Fort Macon State Park) surround the inlet. Since Fort Macon State Park frequently receives dredge disposal material, the western shoulder of Beaufort Inlet has less value than the eastern shoulder on Cape Lookout National Seashore to fish and wildlife resources. So the presence of the conservation tracts prevents Beaufort Inlet from having a low habitat value, but the presence of hard stabilization, dredge disposal and a deep navigational channel prevent the inlet from having a high habitat value. Thus Beaufort Inlet's overall value is a resource category of 3, or medium value.

VII. *Nearshore (0 to 30 ft water depth)*

The nearshore region of the project area is defined for this analysis as marine waters from 0 to 30 feet water depth, from Cape Lookout in the east to the military exclusion areas of Camp Lejeune to the west. Evaluation species for this area include Gulf kingfish, Florida pompano, king mackerel, Spanish mackerel, bluefish, gag, southern flounder, spot, red drum, menhaden, American shad, striped mullet, shrimp, bottlenose dolphin, coquina clam, mole crab, sand dollar, a polychaete worm, moon snail, star coral, Quilling piddock, *Sargassum*, brown pelican, least tern, common tern, red phalarope, northern gannet and Cory's shearwater.

The fishery resources utilizing this zone are commercially and recreationally valuable species, supporting sport fishing tournaments, pier fishing, surf casting and beach seining. At least two evaluation species of fish utilize the surf zone area, where waves break in shallow water, as a nursery area for juveniles (Florida pompano and Gulf kingfish). Other fish rely upon the currents and waves within the nearshore area to disperse larvae between life history stages (e.g., Atlantic croaker). Peterson and Wells (2000) found this area to be dominated by polychaete worms, bivalves, nemerteans, small crustaceans, echinoderms and gastropods (in decreasing order of abundance); altogether 16 separate phyla of benthic fauna were documented. The same surveys found 51 species of demersal fishes in the nearshore Bogue Banks area, with the most abundant species being Atlantic croaker, weakfish (*Cynoscion regalis*), pigfish (*Orthopristis chrysoptera*), pinfish (*Lagodon rhomboides*), kingfish (sea mullet, *Menticirrhus* sp.), silver perch (*Bairdiella chyrsoura*), American silverside (*Menidia menidia*) and spot (Peterson and Wells 2000).

There is an offshore dredge disposal site seaward of Beaufort Inlet utilized as a demonstration project for nearshore disposal of dredge material. The shoals near this area contain a shipwreck thought to be the *Queen Anne's Revenge*; this site and potentially a few others are archaeological resources of high value. The extensive shoals at Cape Lookout have been designated a HAPC for their high value to fishery resources. At the western portion of the project area livebottom (or hardbottom) habitats are present on the seafloor; the precise extent of these productive areas in the nearshore is not known.

The recent dredge and fill project at Pine Knoll Shores and Indian Beach utilized part of this area as a dredge site for fill material, removing the top few feet of substrate. The diversity of fishery resources and benthic fauna found prior to this dredging indicate the nearshore area's value to marine fish and wildlife resources, however. The increasing number of offshore dredge sites for beach fill projects and offshore disposal sites, plus commercial trawling disturbances, indicate an increase in the spatial area of disturbed benthic marine habitats (or a decline in undisturbed areas). For instance, the Dare County (Bodie Island Portion) Beaches dredge and fill project will disturb 7 square miles of benthic marine habitat over the life of the project, generating a decline of 7 square miles of undisturbed benthic habitat (USACE 2000). The new ODMDS near Cape Fear will further disturb an anticipated 9.4 square nautical miles of marine benthos (EPA 2001).

The diverse array of fish and wildlife resources found in the nearshore project area and increasing disturbances to similar areas support a resource category determination of 2, or high value, for the nearshore area of the Bogue Banks Shore Protection Project study area.

VIII. *Offshore (> 30 ft water depth)*

The offshore marine section of the project area extends from 30 to approximately 60 feet water depth, or a distance roughly equivalent to 1 to 5 miles offshore Shackleford and Bogue Banks. This area contains artificial reefs, numerous shipwrecks and areas of both soft and hard bottom habitats. The proximity of the Gulf Stream to Cape Lookout generates a mix of tropical and temperate species. Evaluation species for this area include King mackerel, Spanish mackerel, bluefish, gag, southern flounder, spot, red drum, menhaden, striped mullet, bottlenose dolphin, sand dollar, moon snail, star coral, the boring bivalve Quilling piddock, *Sargassum*, Cory's shearwater, and northern gannet.

Ecotourism, commercial and recreational fishery industries utilize this area for its diversity of fishery resources, diving sites and spotting seabirds and marine mammals. The shoals at Cape Lookout have been designated a HAPC and border this area to the east. Hardbottom or livebottom areas have also been designated as essential fish habitat in recognition of their high value to fishery resources. Hard and soft coral, sponges, tunicates, algae and a variety of encrusting and boring mollusks rely upon hard bottom or rocky substrates as their benthic habitat. These areas are limited in their extent and vulnerable to burial by soft sediments. The macroalgae *Sargassum*, an evaluation species, requires less than 6 centimeters of sediment cover, for instance (Riggs et al. 1998). While relatively abundant within Onslow Bay, these hardbottom areas are limited nationally. The mixing of tropical, temperate and arctic oceanographic currents creates a unique assemblage of pelagic species for the project area. As a result of these factors, the offshore project area has a resource category of 2 to reflect its high value to evaluation species.

Future Conditions Without Project

This report assumes that the several ongoing and proposed projects in the Bogue Banks project area will occur without this shore protection project. Maintenance dredging of the Morehead City state port and associated navigational channels will continue. Periodic maintenance dredging of the AIWW through Bogue Sound will also continue. A new dredged material island is likely to be constructed in Bogue Sound near Peletier Creek, and the island's design will include several environmental enhancement features. The Beaufort Inlet navigational channel will continue to be maintained at an approximate depth of 45 feet. The federal navigational channel through Bogue Inlet will be periodically dredged, with dredged material placement on western Emerald Isle beaches. The nearshore and offshore disposal sites will be filled to capacity and new marine disposal sites sought.

We also assume that the Section 933 project under study for Pine Knoll Shores and Indian Beach will be feasible, expanding dredged material placement from Brandt Island to those communities as well as Atlantic Beach. Atlantic Beach and Fort Macon will continue to receive dredged material from maintenance dredging of Morehead City and Beaufort navigational channels. The Town of Emerald Isle is developing a permit application to dredge a new, larger channel through Bogue Inlet to redirect tidal currents away from vulnerable structures at The Pointe. Sediment dredged during this project is assumed to be placed on the beaches of western Emerald Isle.

The locally funded beach fill project has completed the first phase of three, covering 6.75 miles of oceanfront beach with 1,733,580 cubic yards (cy) of fill material. Phase II is proposed for construction from November 16, 2002 through April 15, 2003 along 7.5 miles of oceanfront beach in Indian Beach and eastern Emerald Isle, and the without project condition assumes this phase will be constructed using up to 2,050,000 cy of fill material dredged from the seabed immediately offshore Bogue Banks.

The Phase II sediments for this locally funded project contain an average of 42% carbonate material, which Carteret County's sample data indicate consists of clam shells, *Donax* spp. shells and other crushed shells of various grain sizes. Thus the material being placed on the beach will increase the carbonate content of the natural beach sediments, which average 20% or less (CSE and Stroud 2000; Appendix G). Without the federal project that is the subject of this report, the local beach fill project will continue to be the without project condition.

Other assumptions are also included in the without project condition. The high number of federal, state and academic research institutions in Morehead City and Beaufort will continue to generate scientific data on the physical and biological environment in and around Bogue Banks (e.g., Reed and Wells 2000, Roessler and Wells 2001). The shipwreck thought to be the *Queen Anne's Revenge* will continue to be excavated and Beaufort Inlet will continue to be studied because of this archaeological value. The estuarine and marine waters in Carteret County will continue to support a large fishing industry, several fishing tournaments and increasing ecotourism.

Finally, sea level is assumed to be rising at an accelerating rate and coastal development will continue. The rate of sea level rise is assumed to be that summarized by Riggs (2002), increasing from 1.01 - 1.06 feet per century at present to 2.8 - 3.2 feet/century by 2100. The present loss rates of estuarine fringe habitats are 1,166 acres per year along 1,593 miles of shoreline in the Albemarle-Pamlico estuarine system, with the highest erosion rates along marsh shorelines (as compared to sediment banks, bluffs and swamp forests; Murphy 2002). In a 50 year period without the project, these rates would result in the loss of at least 91 square miles of estuarine fringe habitat in northeastern North Carolina (the total length of estuarine shoreline in NC is close to 4,000 miles, and this loss is calculated for 1,593 miles of that total). In 1976, approximately 19 miles, or 8.5%, of estuarine shoreline in Core and Bogue Sounds was artificially stabilized (Riggs 2002). This trend has likely increased since then and is assumed to continue in the without project condition. The Bogue Banks shore protection project is aimed towards protecting oceanfront areas, however, and would not affect these estuarine loss rates.

Development, and associated shoreline protection measures, has been increasing along American coastlines (Nordstrom 1994). Indeed, the "dominant agent of landform change is earth-moving machinery" (Nordstrom 1994, p. 479). An analysis of shoreline evolution in New Jersey found a shift over time from "extensive use of groynes, through a period of extensive construction of shore-parallel structures (bulkheads, seawalls, revetments), to the present emphasis on beach nourishment" (Nordstrom 1994, p. 491). "Federal funding increases the likelihood of human alterations and their scale. ... The sequence of human alterations on the New Jersey coast [for example] indicates that the occupation of the coastal fringe is widespread, inevitable, and incontrovertible under present management practice" (Nordstrom 1990 as cited in Nordstrom 1994, p. 502). Peterson and Manning (2001) also note the increasing trend in coastal development and shoreline stabilization projects in North Carolina. Nordstrom (1994) concludes that "the precedent established on the barriers in New Jersey and many other developed barriers in the USA indicate that there may be fewer" locations that are naturally functioning systems in the future (p. 504).

In New Jersey, for instance, the barrier island coastline was originally low-lying, narrow and backed by fringing marshes prior to development. Overwash occurred, covering backbarrier marshes and creating upland habitat in places. The natural dune geomorphology consisted of isolated hummocks of dunes, with 28.3% of the islands having no dunes at all (Nordstrom 1994). "The coastal barriers appeared to be highly mobile prior to human development" (Nordstrom 1994, p. 486). As development occurred along the barriers, the dunes were flattened, "natural vegetation was destroyed," marshes were filled, channels were dredged through the marshes, and the bays were filled to allow construction of causeways and new buildings (Nordstrom 1994, p. 486). "Native plant species are prevented from recolonizing on most of the barriers because of the human preference for using lawn grass and exotic shrubs and trees for landscaping. ... Natural vegetation other than foredune communities only remains in a few natural zones that are maintained as preserves" (Nordstrom 1994, p. 487).

Considering an increase in the rate of sea level rise, Nordstrom (1994, p. 501) describes two potential future conditions for New Jersey ("without regard to human action") that were proposed by Psuty (1986): (1) drowning in place, or (2) island migration through inlet sedimentation, overwash and wind transport of sand across the island. A separate postulation put forth by Titus (1990) includes four future scenarios: "(1) no protection, leading to eventual abandonment (although development compatible with a dynamic barrier is still possible); (2) engineered retreat that mimics natural retreat by artificially filling the bay sides of barriers while the oceanside erodes; (3) raising the barrier in place by placing sand on the beach and concomitantly raising buildings and support infrastructure; and (4) constructing seawalls and flood protection structures around the barrier, creating a ring-levée enclave" (Nordstrom 1994, p. 501).

Nordstrom (1994) describes a closed system of coastal evolution over time, trending towards hard stabilization where beaches and dunes are replaced by bulkheads and seawalls. The assumptions used by Nordstrom (1994) in a without project condition include that "shoreline mobility will be reduced in areas protected by structures; [and] ... inlets that are now dredged will continue to be dredged, and existing channels will be maintained in place" (p. 500). Beach nourishment options have the potential for more natural processes than hard stabilization options, though (Nordstrom 1994). In order to restore more naturally functioning systems, beach nourishment projects need to incorporate habitat improvement features and nature based tourism in addition to flood control and storm protection features. Compromises must be sought, resulting in semi-natural systems that balance the needs of all stakeholders (Nordstrom 2001).

The trends observed by these researchers are incorporated in the Service's without project condition for Bogue Banks. That is, development will continue, shoreline stabilization will continue or increase, and rising sea level will require compromises to balance development with geomorphic responses to higher sea levels. Natural ecological communities will be altered or lost over time as current disturbance and loss rates continue.

SECTION 7. ALTERNATIVES CONSIDERED

As provided by the Corps to the Service on June 17, 2002, the preliminary alternatives under consideration are described as the following:

"A no action plan, non-structural alternatives, and various configurations of beach fills will be evaluated as described below for the Bogue Banks Shore Protection study. All alternatives will have to be consistent with the Coastal Area Management Act.

1.0 Without Conditions (No Action).

"Under a no-action alternative, there would be no federal participation in hurricane and storm damage reduction for the project area. However, a "no action" plan would not preclude temporary or emergency measures, such as beach scraping, sandbagging, and non-Federal beach nourishment. Non-Federal beach nourishment may not be adequate for the long-term, but could take place as a short-term measure.

2.0 Nonstructural Alternatives.

"Potential non-structural measures that will be considered include (1) retrofitting existing buildings, (2) stricter zoning and setback requirements and building codes for new buildings (3) relocation, and (4) evacuation. Retrofitting existing buildings may allow some structures to withstand some levels of storm and erosion forces. Stricter zoning requirements and setbacks, as well as stronger building codes could minimize storm and erosion damages to structures that have not yet been built.

"Relocation is the movement of a structure to another parcel of property. Evacuation would involve a buy-out program. As long-term erosion approaches a structure, it may undergo relocation to safer ground if sufficient time, funding, and an acceptable alternate site are available, or, alternatively, the structure could be purchased with public funds, demolished, and subsequently removed.

3.0 Structural Alternatives.

"Structural alternatives may include:

"A. The construction of seawalls and/or revetments, groin fields, breakwaters and/or submerged rubble mound reefs, and tee head groins.

"B. The placement of beach quality sand on Bogue Banks.
"Two types of alternative beach-fill sections may be evaluated: 1) a beach berm, and 2) a dune and berm. These proposed beach-fill sections are described below.

“ 1. Beach Berm Plans. The berm is a fill extending seaward from the existing profile, with an elevation of about 7 feet NGVD. Berm width is measured seaward along the top of the berm from the point where the top of berm intersects the natural profile. Seaward of the designed berm width, the with-project profile parallels the existing profile out to the closure depth of –22 feet NGVD. The widths evaluated may include 50, 100, and 150 feet.

“ 2. Dune and Berm Plans. Existing dunes were assumed to remain in place, with the designed dunes tying into them where appropriate. Designed dune templates were tied to a construction line, which is based on both the existing shoreline and the existing development. The landward slope of the dune template is 5 feet horizontal to 1 foot vertical, the top of the dune is 25 feet wide, and the 5 feet horizontal to 1 foot vertical seaward slope. The berm elevation is about 7 feet NGVD, with berm width measured from the toe of the constructed dune. Seaward of the designed berm width, the with-project profile parallels the existing profile out to a closure depth of –22 feet NGVD. Top of dune elevations of 13 and 15 feet NGVD may be evaluated with a 50-foot berm at elevation 7 feet NGVD. A 13-foot high dune with a 25-foot berm at 7 feet NGVD may also be evaluated.

4.0 Alternative Borrow Sources.

“Central to the consideration of any beach fill alternative is the availability of environmentally acceptable borrow sites with material of sufficient quality and quantity to construct and maintain the project for it’s authorized life. Investigations for borrow material may be made at Bogue and Beaufort Inlets, Brandt Island, offshore of Cape Lookout to Shackleford Banks, within the estuary, the area offshore of the area where the project is proposed, Morehead City navigation channels (i.e., Range A, the Cutoff, etc.), the United States Environmental Protection Agency (USEPA) designated Morehead City Ocean Dredged Material Disposal Site (ODMDS), and the nearshore area.“

SECTION 8. IMPACTS OF THE PREFERRED ALTERNATIVE

This section describes the potential ecological impacts of an artificial beach and dune construction alternative, as it has been the preferred alternative for similar Corps shoreline stabilization projects in North Carolina. If another alternative is selected as the Corps National Economic Development (NED) plan, substantial revisions will need to be made to this draft report to address the impacts of that alternative.

The Service has previously summarized the documented impacts of artificial beach and dune construction projects in USFWS (1999), USFWS (2000a), USFWS (2000b), USFWS (2001) and USFWS (2002a). These reports are incorporated by reference as their findings are applicable to this project as well, and this section supplements those reports with new scientific information not included in them. Recent studies and literature not previously reviewed expand the scientific knowledge of ecological impacts and recovery following dredge and fill projects. This information includes impacts during dredging at the dredge site and the physical environment that defines various microhabitats for invertebrates (the prey for birds and fish), fish, birds, and sea turtles.

Potential Impacts at the Offshore Dredge Site Habitats

The Minerals Management Service (MMS) is a bureau within the U.S. Department of the Interior that oversees the dredging of offshore materials from the seafloor, which are known as aggregate in the mining industry. The MMS issues appropriate permits or leases to dredge material from the seafloor more than three nautical miles from the shoreline. Recent proposals to dredge sands from waters under the purview of the MMS for beach nourishment projects has fostered several environmental studies by and for the MMS. One such report recently prepared for the MMS summarized the marine mining technologies and mitigation techniques currently available, including those for beach nourishment projects (C-CORE 1996). The findings of this report are summarized here, with the Executive Summary of the report reproduced in Appendix H; the entire report is available on-line at http://www.mms.gov/intermar/studies.htm.

While most species live within the upper 1 meter of the seabed (due to its aeration with oxygen), some larger species may live deeper in the seabed (1 to 2 m). "Large deep-living forms present a further concern [for ecological impacts] in that they may be long-living, slow-growing forms whose biomass may have taken 100 or more years to form. Once these forms ... are lost [through removal of the sediments] it may take decades to reestablish a potentially sustainable fishery. The loss may even be permanent" (C-CORE 1996, p. 13). The presence or absence of these species in the Bogue Banks project area are not known.

The recovery of the dredge site ecosystem depends on the sediment grain size, with fine-grained deposits (muds, silts, clays) achieving similar biodiversity levels within 1 year, medium-grained sands within 1 to 3 years, and coarse-grained deposits (> 2 mm) within 5 years or more. Recovery is defined by the authors as "a successional community of opportunistic species providing evidence of progression towards a community equivalent to that previously present, or at non-impacted reference sites" (C-CORE 1996, p. 22). The significance of the rate of recovery is unknown as other reports have documented recovery times of a few months to a few years for the offshore dredge sites (MMS 1999; Posey and Alphin 2000; Posey and Alphin 2002; Ray 2001; Van Dolah et al. 1992, 1994).

The C-CORE (1996) report makes several recommendations to avoid and minimize potential impacts to the marine ecosystem. For instance, in order to avoid the ecological impacts from the release of anoxic or toxic pore water from seabed sediments, patches of fine silts and clays that may occur within a dredge site should not be dredged. This potential impact is not likely to be significant for the Bogue Banks project because the high percentage of seawater within the dredge slurry (~85%) would dilute and mix any pore water with aerobic seawater. Also, the preferred sediment sources for dredge and fill projects are dominantly sand and avoid high concentrations of silts and clays.

The C-CORE (1996) review states that the level of suspended sediments generated by a cutterhead dredge rises exponentially with increasing cut thickness, rate of cutter swing, rate of cutter rotation and rate of production (Barnard 1978 as cited in C-CORE 1996, p. 137). Elevated turbidity levels at the seabed may occur up to 300 m from the cutterhead. This potential impact should not be significant for the Bogue Banks project if the dredge areas are located greater than 300 m from any hardbottom areas that would be adversely affected by increased turbidity levels.

Turbidity plumes generated by aggregate dredging may persist for long periods of time, potentially reducing light penetration and associated primary productivity; the planktonic food web may be affected as a result, although the turbidity plumes may have little or no impact on zooplankton (C-CORE 1996). The significance of this potential impact will depend on the project design since the impact should be temporary. The frequency of dredging may cause a persistent turbidity plume that reduces primary productivity for the life of the project if construction occurs on an annual basis similar to the Dare County (Bodie Island Portion) Beaches project (USACE 2000). The significance of this impact also depends on ambient turbidity levels within the project area, which may or may not be within the expected turbidity range of the dredging.

The dredging of seabed sediments temporarily may increase biological activity within the dredge site by attracting predators and scavengers to newly exposed, injured or killed organisms within the disturbed areas. The area may become "more attractive to fishing [as a result] but at unsustainable levels" (C-CORE 1996, p. 13). Some crustaceans (crabs, lobsters and others) that are omnivorous and live on the seabed may be able to survive smothering and burial resulting from turbidity plumes more easily than other less mobile epifauna. The authors theorize that this survival is enabled by the increase in prey for the crustaceans from other damaged species. The significance of this impact for the Bogue Banks project will depend upon the location, size and frequency of use of the targeted dredge site(s).

The sensitivity of the benthic community to a change in seabed sediment size varies with the species (C-CORE 1996). Some polychaete worms and crabs can be insensitive (or tolerant to changes in the seabed sediments) while "fishery species with dependent, specialist feeding and habitat requirements" are more sensitive to changes (C-CORE 1996, p. 23). The authors recommend identifying tolerable habitat changes prior to dredging and monitoring and mitigating appropriately. This potential impact can likely be avoided or minimized for the Bogue Banks Shore Protection Project by development of thresholds of change in coordination with resource agencies and other interested parties.

The biodiversity of the seabed community naturally fluctuates on an annual basis and many species occur in clusters rather than a uniform distribution across the seabed (C-CORE 1996). Many benthic-feeding fishery species, however, consistently are found in the same areas (commonly known as "fishing grounds") and their presence or absence is not directly related to the patchiness or annual fluctuation of their benthic prey. Survival of species with high territoriality (e.g., groundfish, marine mammals, birds) may be reduced if the dredging activities force the creatures away from their home sites. In addition, entire populations of species that make mass migrations along set routes during set seasons (e.g., marine mammals, sea turtles, marine birds, some fish and crustacea) may be exposed to dredging-induced impacts if the dredging occurs within their routes or migratory seasons. These potential impacts can be avoided through the appropriate site selection of the dredge site(s) for the Bogue Banks project.

Marine mammals that rely upon echolocation or sonar for feeding and travel are likely to be at risk from high noise levels from dredge operations, affecting foraging, breeding and their ability to protect themselves (C-CORE 1996). Equipment and vessel noise may be detected by marine mammals up to 190 kilometers (km) or more away, and behavioral changes may occur at 40 km or farther. The authors recommend making the dredges as quiet as possible and implementing a detailed recording of all on-board observations of marine mammal and other wildlife's reactions to the vessels and equipment. Another analysis summarized that most marine dredges may generate noise that exceeds the ambient noise level up to 25 km away from the vessel, but that the noise level varies with the individual dredge, with some dredges capable of emitting noise that is detectable at greater distances (Richardson et al. 1995). Several marine mammal species utilize the waters of the Bogue Banks Shore Protection project area, but the ambient noise levels in the project area without the project are not known. The presence of a deepwater port with tanker traffic may produce higher noise levels than marine dredges, but the latter noises tend to have longer durations than the commercial vessels (Richardson et al. 1995). Thus the significance of the potential noise impact from marine dredges utilized in the Bogue Banks Shore Protection Project is unknown and should be monitored in order to determine its significance.

In regards to ecological monitoring of dredge and fill projects, C-CORE (1996) concludes that the monitoring of impacts to the water column and its biological community is usually inadequate and does not sample on a frequent enough schedule to detect short-term impacts. The monitoring should be high intensity over a short period of time, with the goal of determining if water quality guidelines are being met. One example cited in the report was a beach nourishment project near Jacksonville, Florida, where the MMS required that nephelometer readings at the water surface, mid-depth and bottom not exceed 29 nephelometer turbidity units (NTU) at any time during the dredging operations. Preliminary data sampled along the beaches of Bogue Banks following the locally-funded beach fill project indicate that turbidity may exceed ambient levels for extended periods of time (Appendix G), generating a potentially long-term adverse impact.

Other studies have similar findings to those of the C-CORE (1996) report. The Dare County Beaches (Bodie Island Portion) project, for instance, may include dredging in the wintering grounds of striped bass (*Morone saxatilis*), a migratory fish species that may be significantly affected as a result (Laney et al. 2001). Downcurrent turbidity and sedimentation reduced the area available for recruitment of sessile epifauna by covering hardbottoms following dredging in the North Sea of the United Kingdom; the loss of adults stock subsequently reduced the possible juvenile recruitment in the area (Kenny and Rees (1994, 1993)).

Salomon et al. (1982) provides a survey of the high intensity, short-term nature advocated by C-CORE (1996). This project monitored the short-term recovery of dredge pits offshore Panama City, Florida, after dredging in the summer of 1976. The authors documented the rapid recovery of the benthic community of the dredge pit within 3 weeks post-dredging. Full recovery of the site was documented within one year. The researchers attribute the rapid recovery of the benthic community to the high wave energy environment (6 to 9 m water depth), the similarity of sediments exposed in the base of the pit to those present pre-dredging, and the quick burial of the silt and clay sediments that initially settled within the pit by sands moved into the pits by waves and currents. The dredge pits were excavated to 3 to 5 m deep and were filled in to 1 m below grade within the first year post-dredging. This study supports the findings of others that the sediments exposed by the dredging activities should closely match those exposed prior to the dredging in order to enable rapid recovery of a similar biological community.

More recently, Posey (2001) and Posey and Alphin (2002) monitored the recovery of the offshore dredge pit for a beach fill project at Kure Beach, North Carolina, for 2 years prior to 2 years after dredging (1995-99). The data from this study "suggest relatively quick recovery from borrow activities with interannual variability explaining more of the observed differences than sediment removal effects." The timing of the dredging (in fall and winter) prior to peak infaunal recruitment periods, the opportunistic nature of several of the invertebrate species, and the limited size of the dredge site may be key factors responsible for limiting the long-term impacts from the sediment removal.

Ray (2001) found that the infaunal community at the offshore dredge site for a large-scale project in New Jersey was "numerically dominated by the archiannelid polychaete *Protodrilus* (LPIL), the amphipod *Pseudunciola obliquua*, and the tanaid *Tanaissus psammophilus*. Biomass was dominated by the sand dollar *Echinarachnius parma* as well as *S. solidissima*, *Ensis directus*, and the tellinid *T. agilis*, or a suite of polychaetes including *M. papillicornis*, paraonids, cirratulids, and nepthyids." The dredging of beach fill material "resulted in decreased total abundance, biomass, taxa richness, and the average size of sand dollars. Species and biomass composition were altered in similar manners by each dredging operation: immediately after dredging the relative contribution of echinoderm biomass declined and the abundance of the spionid polychaete *Spiophanes bombyx* increased" (Ray 2001). The species abundance rapidly recovered following two dredging operations (1997 and 1999), "with no detectable difference between dredged and undisturbed areas by the following spring" (Ray 2001). The biomass and average size of the sand dollars, however, needed 2 to 2.5 years to fully recover.

Potential Impacts to Oceanfront Beach Habitats

Oceanfront beaches are highly dynamic habitats, continuously evolving in sediment volume, shape and substrate characteristics. Swales (2002), for example, found a statistically significant variation in the volume of sediment on a beach every 5.8 days. The author also found that at least 8 equally spaced transect profiles were necessary to reproduce the beach morphology accurately due to the spatial variability of beach habitats. This high dynamism lends further support to the recommendation for high-intensity, short-term monitoring to adequately document positive and negative impacts of a large scale dredge and fill project (C-CORE 1996).

The substrate in which sandy beach macrofauna burrow is influenced by both physical and biological processes. Meadows and Tait (1989) conducted laboratory experiments with a burrowing amphipod (*Corophium volutator*) and polychaete worm (*Nereis diversicolor*) to test alterations to the permeability and shear strength of estuarine muddy sands from bioturbation. Their study found that bioturbation by these burrowing organisms affects the permeability, water content and shear strength of the sediments. Water content decreased and shear strength increased with increasing densities of the two organisms, while permeability decreased with increasing numbers of the amphipod and increased with higher numbers of the polychaete (Meadows and Tait 1989). This indicates that the physical and biological features of a beach ecosystem are closely linked and share a complex interaction.

Several studies have shown that the fauna that live within a beach (the infauna) are indeed adapted to the physical parameters defining beach microhabitats. McArdle and McLachlan (1992) analyzed the physical habitat features important to sandy each macrofauna such as coquina clams, for instance. The authors "argue that swash climate on the beach face is the most important aspect of the environment experienced by animals inhabiting exposed sandy beaches" (McArdle and McLachlan 1992, p. 398). Several bivalves, crustaceans and gastropods are "swash-riders" that move up and down the intertidal portion of the beach with incoming swash and fluctuating tides. This study found that the wave height and beach slope are the two key factors responsible for the swash climate. The swash climate in turn affects the amount of water infiltrated into the beach and available to filter feeding organisms. The authors conclude that coquina clams are particularly sensitive to beach slope, and that "*Donax* sp. may select parts of a beach with flatter slopes *via* swash climate variables, *i.e.* an indirect response to slope *via* direct response to swash climate" (McArdle and McLachlan 1992, p. 405). Furthermore, they cite (McLachlan 1990) as support for the finding of macrofaunal sensitivity to beach slope and swash climate, stating that "there is a linear increase in intertidal macrobenthic species richness and a logarithmic increase in total abundance from reflective [steeper] to dissipative [flatter] beaches as well as a decrease in mean individual body size" (McArdle and McLachlan 1992, p. 405).

McLachlan et al. (1995) also found that bivalves are adapted to different beach types. The ability of the bivalves tested, including *Donax* sp., to burrow into sediments was not affected by beaches that were low wave energy and coarse sand, but were to high wave energy beaches with fine sand. Juveniles tend to burrow faster than adults. The authors conclude that "small species with high density and streamlined shape are best adapted to the dynamic swash conditions that characterise reflective beaches" (McLachlan et al. 1995, p. 147).

These studies suggest that to the extent that a beach fill project modifies the beach slope and/or wave energy climate, the project alters the specialized habitat of indicator species like coquina clams. If the beach is flat or dissipative pre-project, and if the addition of fill material or maintenance beach scraping steepens the beach, the species richness, abundance and size of individual organisms may be affected. These potential impacts may be significant in both a long-term and cumulative sense.

The fauna that live within a beach rely upon the continual input of sea water to provide food (since they tend to be filter feeders) and oxygen and to remove waste products. McLachlan et al. (1985) studied the infiltration of water (and thus the source of oxygen and food for filter feeding infauna) on beaches in western Australia with and without beach cusps and wrack material. The mean residence time of sea water filtered into a beach by wave swash was from 1 to 7 hours and percolated through 2 to 5 m of sediments. More water infiltrated into the beach on beach cusp horns than on embayments, with the net flow into the beach on the horns and out of the beach (as effluent) on the embayments. [Donoghue (1999) found that coquina clams preferred beach cusp horns to embayments.] Most of the sea water filtered into the beach through the upper part of the swash zone, where the water table was less than 20 cm from the beach surface. Chemical analysis of the interstitial water, or the water between the sand grains, yielded high concentrations of nutrients, and of phosphate in particular. The nutrient concentrations within the beach sands were greater than the water within the adjacent surf zone, and leachates from decomposing wrack material increased nutrient concentrations in the upper intertidal zone. Beaches composed of carbonate (shelly) sands may be comparably deficient in phosphate, however, due to its removal by the carbonate (McLachlan et al. 1985). Thus the removal of wrack material or addition of high shell contents as part of a beach fill and maintenance program may affect the nutrient cycling within a beach, and the meiofauna and filter feeding macrofauna accordingly. No nutrient data are known as of this time for the immediate project area.

The color of beach fill materials is another physical substrate parameter and has both ecological and aesthetic value. Ecologically, the color of the sediments may affect their temperature. Monitoring of the temperature of native and beach fill sediments placed on Bogue Banks during 2001-02 is currently underway by the NC Wildlife Resources Commission and preliminary results should be available soon. Previous reports by the Service summarized the affect of color and sediment temperature on incubating sea turtle nests (e.g., USFWS 1999, 2000a, and 2000b).

Browder (2002) describes the use of the Munsell Color Scale to determine the color compatibility of potential sand sources with the native sands of Pensacola Beach, Florida. The project sponsors designated the mineralogy (99% quartz), mean grain size (0.33 mm), sorting coefficient (0.47 phi) and color (Munsell Color Value of 9.25 or whiter and a chroma of 0.5 or less on the 2.5, 5, 7.5 or 10YR scale) for compatible sediments. The color and composition of the sediments were more important than the economic viability of obtaining the sediments to the local sponsors, and Escambia County passed an ordinance requiring any beach fill materials placed on Perdido Key or Santa Rosa Island have a Munsell color of 10YR 9.25/0.5. In order to meet this color criteria, exposure and oxidation testing was conducted on potential sediment sources to simulate weathering and bleaching of the fill material after placement. The solar exposure tests found that very little additional bleaching of the materials occurred after the first two weeks. Oxidation tests that washed the potential sediments with hydrogen peroxide produced similar results as the exposure tests, so the researchers concluded that the oxidation test adequately approximated the amount of initial lightening expected to occur following beach placement (Browder 2002). These methods provide a new way to ensure acceptable sediment compatibility in projects where color may be an issue, avoiding potential impacts to fish and wildlife resources.

Some beach fill construction and maintenance activities affect the dune system at the back of the beach as well as the wide, flat portion of the beach (the berm) and the intertidal areas. Shoreline stabilization projects often lead to the loss of natural features of beaches such as dunes, vegetation, and wracklines (Nordstrom 2000; Nordstrom 2001). Dunes built as part of a shoreline stabilization project often are designed as dikes, with "the location of the dune on the beach profile ... different from [its] location under natural conditions because [the] dune position is dictated by human preference rather than the interplay between vegetation growth, sediment supply and wave erosion" (Nordstrom 1994, p. 494). Extensive use of beach cleaning equipment has led to the removal of vegetation litter that naturally forms dunes. Dunes built by sand trapping with fences or vegetation plantings tend to be larger than would naturally form on those beaches (Nordstrom 1994).

Projects constructed in North Carolina typically involve the construction of a dune ridge as part of the design template. The beach fill used on the beach and to construct the dunes differs from natural windblown sand by containing coarser sediments than the wind would have normally transported to those areas. Nordstrom (1994) argues that nourished beaches are easily distinguishable from natural beaches due to their larger width and "the presence of coarse sediments on the surface of the backbeach. Accelerated deflation occurs [on nourished beaches], but dunes are rarely allowed to form in intensively developed areas [and] drift accumulations on the beach are removed to retain wide, flat recreation platforms" (p. 492). In addition, large buildings along the oceanfront shoreline may modify wind flow patterns, altering windblown sediment transport and accelerating the loss of sediment on the beach (Nordstrom 1994).

Within the project area, Conaway (2000) compared the aeolian transport, or windblown sands, at several dunes on Bogue Banks that had been scraped (bulldozed) and not scraped. Beach scraping artificially modifies the shape of the beach by pushing sediment from the intertidal zone to the base of the dune scarp, or to create an artificial dune or levee (and thereby modifying the physical habitat of intertidal and backbeach fauna and flora). The Conaway (2000) study found that beach scraping increased the amount of sands transported by the wind through increasing the amount of sediment available to be mobilized and by altering the shape of the dunes. The windblown sand transport rates were not significantly reduced by American beach grass (*Ammophila breviligulata*) plantings. "Despite substantial wind erosion, beach/dune profiles indicate that wave action was principally responsible for volume losses observed at scraped dunes" (Conaway 2000, p. ii). While the scraped dunes prevented erosion during minor storm events, they provided only minimal erosion control during a major storm event (Hurricane Floyd). The beach scraping also increased the slope of the beach, "suggesting that more stringent monitoring of scraping projects is necessary" (Conaway 2000, p. ii).

As a beach fill project erodes over time, the fill material also moves into adjacent aquatic habitats either downdrift or offshore. Reed and Wells (2000) mapped the distribution of dredged material sediment offshore Atlantic Beach and Fort Macon at the eastern end of the project area. Sedimentary characteristics were able to distinguish between native sediments, dredged material and relict sediments (or the underlying geology). The color, polish and size of shells were particularly useful indicators of the dispersal of dredged sediments off of the beach fill. Mapping of the distinct sediments suggests that little of the dredged material moved downdrift to Pine Knoll Shores and that cross-shore transport of the sediment (off the beach into deeper water) potentially is more effective at moving the dredged material.

Inlet areas often are targeted as a sediment source for beach fill projects in North Carolina (e.g., Shallotte Inlet, Masonboro Inlet, Mason Inlet, Rich Inlet, Bogue Inlet). Inlet habitats have been increasingly modified over time, via closures, dredging and jetty stabilization. "Dredging at ... inlets has changed the amount of sediment transferred across inlets and has influenced the location of accretion and erosion on adjacent shorelines by either changing the location of tidal channels or maintaining them in place, depending on human preference. ... Maintenance dredging ... keeps the [tidal] channel from fluctuating as widely as it would under natural conditions, and it reduces the periodicity of, or virtually eliminates, erosion/deposition cycles associated with breaching of the ebb tidal delta" (Nordstrom 1994, p. 489). These cycles of erosion and accretion govern the distribution of wet and dry inlet habitats for spawning fish, foraging and nesting birds, and migratory fish, sea turtles and marine mammals. The reduced variability in the distribution of these habitats has an unknown effect on these biota.

Potential Impacts to Sandy Beach Macrofauna

A study of the macrobenthos at Murrells Inlet, South Carolina, by Knott et al. (1983) is one of few studies surveying the invertebrate community at a tidal inlet. Of the 223 invertebrate species identified, polychaete worms were the dominant fauna both in numbers of species and individual populations. The intertidal zones were dominated by the polychaete *Scolelepsis squamata*, the amphipod *Neohaustorius schmitzi* and the coquina clam (*Donax variabilis*). The subtidal infauna were more diverse (208 species versus 88 in the intertidal areas) and were dominated by two polychaete species (*Spiophanes bombyx* and *Scolelepsis squamata*), two amphipods (*Protohaustorius deichmannae* and *Acanthohaustorius millsi*), and a bivalve (*Tellina* sp.). Species numbers and richness increased from the mean high water line seaward to 5 m water depth. Many of the species assemblages, of which the authors found 11, were spatially restricted to specific microhabitats. The authors conclude "that a distinct different in overall community structure exists between the intertidal and subtidal zones..., but it is important to note that many of the numerically dominant species are prevalent in both zones" (Knott et al. 1983, p. 586). They also determined that the invertebrate community structure is affected by the wave energy, with more species diversity, richness and evenness on semi-protected beaches (such as those sheltered by jetties) than at openly exposed beaches.

Several researchers at the University of North Carolina at Chapel Hill's Institute of Marine Sciences (IMS-UNC) have been conducting ecological studies in the project area in the past 5 to 10 years. Lindquist and Manning (2001) studied the impacts of beach bulldozing (scraping) and nourishment on surf zone fishes on Bogue Banks and North Topsail Beach. They found statistically significant declines in ghost crab populations 6 to 8 months following beach scraping, and the crab population did not fully recover prior to the next beach scraping event. "Hence, complete recovery of ghost crabs on beaches that undergo repeated scraping each year is unlikely" (Lindquist and Manning 2001, p. 1). There was no significant difference in the populations of coquina clams and mole crabs between scraped and non-scraped beaches, but the authors note that the high annual variability in populations may have masked any impacts caused by the scraping.

Most recently, these scientists have documented the recovery of infaunal beach populations following beach scraping and beach nourishment activities on Bogue Banks and Topsail Island (Lindquist and Manning 2001; Peterson et al. 2000; Peterson and Manning 2001). Both field surveys and laboratory experiments continue to be conducted by IMS-UNC during 2002 in the local beach fill project area and control beaches on Bogue Banks and Hammocks Beach (Appendix G).

To date the IMS-UNC research has documented that the faunal populations along the 6.75 miles of oceanfront beach that received beach fill between December 2001 and April 2002 are significantly depressed. Coquina clam (*Donax* sp.) and mole crab (*Emerita talpoida*) populations are 80% fewer in the beach fill as compared to control beaches, ghost crab (*Ocypode quadrata*) are 50% fewer, and shorebird abundances are 85% lower. More opportunistic species such as the polychaete worm, *Scolelpsis squamata*, have recovered, however. Turbidity levels within the surf zone are higher at the beach fill than at control sites, and frequently exceed the state salt water quality standards (C.H. Peterson, IMS-UNC unpubl. data, Appendix G).

The beach fill sediments used in this locally funded project were dredged from immediately offshore of Bogue Banks and contained between 30 and 40% carbonate material. In comparison, the native beach sediments of Bogue Banks contain less than 20% carbonate material (shells). Other beach fill projects that utilized beach fill sediments that more closely matched the native sediments showed ecological recovery of infaunal species within 8 months (e.g., Hackney et al. 1996, Ray and Clarke 1999, Saloman and Naughton 1984, Van Dolah et al. 1994).

A higher than background coarse-grained or carbonate fraction can inhibit the burrowing of beach infauna and the foraging of shorebirds (Alexander et al. 1993; Bowman and Dolan 1985; Lindquist and Manning 2001; Peterson et al. 2000). Laboratory experiments testing the sensitivity of burrowing coquina clams to various shell contents found that the clams have slower burrowing times with increasing sediment grain sizes (Lindquist and Manning 2001; IMS-UNC unpubl. data, Appendix G). Similar experiments with the burrowing ability of mole crabs found that burrowing times for large crabs are fastest within unsorted native beach sediments from Bogue Banks (mean grain size 0.177 mm or 2.5 phi) and significantly increase if the sediments are greater than or equal to 2 mm (-1.0 phi) or smaller than or equal to 0.0625 mm (4.0 phi; $P<0.05$). The burrowing times for small mole crabs does not significantly vary with grain sizes equal to or smaller than 1.00 mm (0.0 phi; P<0.05). When the sediment grain size is 4.0 mm (-2.0 phi) or greater, the time it takes a mole crab to burrow is approximately three times as long as when the sediments are unsorted natural Bogue Banks beach sands.

Alexander et al. (1993) also found that *Donax* spp. are substrate sensitive, with their burrowing rates varying with sediment grain size. The maximum burrowing efficiency of coquina clams is in fine sand (0.125 mm or 3.0 phi), with borrowing rates decreasing with both finer or coarser material (similar to the pattern documented for mole crabs by Lindquist and Manning 2001). The coquina clams appear more sensitive to finer grain sizes than to ones coarser than fine sand.

Experiments with shell contents ranging from the natural, unsorted content of Bogue Banks beaches to 80% shell material show that both small and large mole crabs are sensitive to increasing shell content (Appendix G). Significant increases in burrowing time of the crabs occur with 20% shell content as compared to the natural beach sediments of Bogue Banks (P<0.05). The same experiment for coquina clams indicate that their burrowing times significantly increase with 20 to 33% shell content as compared to natural concentrations on a non-nourished beach in the project area (P<0.05; L. Manning, IMS-UNC, unpubl. data in Appendix G). The shell content appears to camouflage invertebrate prey from foraging fish, reducing their ability to effectively forage even when the mole crabs and coquina clams have slower burrowing times (which could make them more vulnerable to predation; Dr. C.H. Peterson, pers. comm. September 4, 2002; Appendix G).

Monitoring of beach macroinvertebrates on North Topsail Beach following dredge disposal events in the springs of 1999 and 2000 found significant impacts to populations of ghost crabs, coquina clams (reduced by 50%), mole crabs (reduced by up to 100%), and several species of amphipods (reduced by half); the individual size distributions for mole crabs and coquina clams were smaller as compared to control beaches (Lindquist and Manning 2001, Peterson and Manning 2001). The dredged material studied in this project resulted in the sediments becoming finer than the pre-project beaches and increased turbidity in the surf zone during the disposal event (Peterson and Manning 2001). Turbidity experiments replicated in the laboratory documented a significant decline in the growth rates of coquina clams (which are filter feeders) by 25% under conditions similar to those measured in the field during the project (Peterson and Manning 2001).

Peterson and Manning (2001) concludes that the "impacts on the benthic macrofauna [at North Topsail Beach] were dramatic and longlasting" since the fauna did not recover in between disposal episodes (Peterson and Manning 2001). "[T]his project resulted in the reduction of habitat value of the intertidal beach for most surf fishes and shorebirds through reduced prey abundance and body size, a compound impact on production and trophic transfer" (Peterson and Manning 2001). Lindquist and Manning (2001) similarly conclude that "the repeated disturbance of beach disposal appears to prevent the full recovery of these populations and consequently results in their decreased productivity and decreased energy flow to vertebrate consumers" (p. 1).

Another recent scientific study conducted to monitor the impacts of dredge and fill projects on macrofauna was held in New Jersey. Ray (2001) found that the intertidal macrofauna species assemblage was similar to those found at other mid-Atlantic sandy beaches, with polychaete and oligochaete worms, haustoriid amphipods and mole crabs dominating the abundance. Many of the same species were found in the nearshore assemblage, but this assemblage was dominated by coquina clams and different species of polychaetes, amphipods and bivalves.

The sampling found that the abundance of the macrofauna peaked in the summer and was lowest in the middle of winter. The short-term impacts resulting from two beach fill episodes to the infauna included declines in taxa richness, biomass and abundance. At the mean low water line, the macrofauna recovered within 2 to 6.5 months of the beach fill placement. The researchers attribute differences in the recovery rates to the timing of when the beach fill operations were completed. The first beach fill episode (1997) resulted in no detectable change to subtidal infauna at 1 m water depth and the nearshore study area. The second beach fill episode (1999-2000) detected impacts persisting at 6 months post-construction. The reduced abundance and biomass measurements were within the variability of baseline conditions measured at non-nourished beaches, however (Ray 2001).

Rakocinski (2001) summarized a study on the impacts to macrofauna in various microhabitats on Perdido Key, Florida. The researchers posit that the more diverse species assemblages found offshore are less resilient to dredge and fill projects than those in the nearshore and beach habitats. An increase in the silt and clay loading occurred offshore following beach disposal and nearshore disposal of sediments (referred to as "profile nourishment" by the author), and this increase resulted in a change in benthic community structure for at least two years following construction. Total density and species richness decreased following the dredge and fill activities, the variability in these parameters increased, and the abundance of indicator species became more variable as well (Rakocinski et al. 1996).

Similar to the argument of Rakocinski (2001), Reilly et al. (1980) noted a difference in recovery of nourished beaches depending on the dominant community structure. Intertidal communities dominated by mole crabs and coquina clams, which have pelagic larval stages, may recover rapidly if the nourishment ends prior to the spring larval recruitment period. Beaches dominated by invertebrates who live their entire life histories on the beach (with no pelagic larval stage, e.g., *Haustorius* spp.) will have significantly longer recovery periods. The authors also state that beach nourishment activities typically increase the turbidity of adjacent waters by 3 to 4 times above the background level. Their conclusions recommend timing construction activities to avoid larval recruitment periods, use compatible materials to minimize turbidity, and to utilize "a few smaller sized non-continuous projects rather than one large one (to allow nearby 'seed' areas for organisms not recruited by pelagic larvae" (Reilly et al. 1980, p. 269).

Diaz (1980) conducted some of the earliest research on the mole crabs of Bogue Banks in 1972 and 1973. This research documented the life history of mole crabs in the project area, finding that the average lifespan of the mole crabs is about 2 years, there are two reproductive periods (spring and summer), recruitment of juveniles peaks during June-July and September-October, and that individuals may move downdrift along the beach anywhere from 10-15 m to 4-5 km in a single day (but no mass active migrations were measured, only passive transport on longshore currents). The author noted another study (Wolcott 1978) which found that although mole crabs constituted 41% of the diet of ghost crabs at Fort Macon, the mole crab population is not controlled by the ghost crabs. This life history information is useful in determining periods of high biological activity in the study area and potential recovery mechanisms (e.g., recolonization of a fill area by adult or larval recruitment).

Potential Impacts to Fish

The data available on potential impacts to fish from dredge and fill projects has been receiving increased attention. The high number of research organizations (federal, state and academic) in Carteret County has generated more data on fishery resources in the project area than any previous project in North Carolina.

Peters et al. (1995), for instance, studied the abundance of larval fish at Beaufort Inlet prior to an anticipated dredge disposal project at Atlantic Beach. At least 36 taxa (with 29 identifiable species) were collected in both larval and early juvenile states. The most abundant species were spot (*Leiostomus xanthurus*), Atlantic menhaden (*Brevoortia tyrannus*) and Atlantic croacker (*Micropogonias undulatus*). The abundance of larval and early juvenile fish varies with the seasons, with February, March and early April the months of peak abundance and therefore "probably not good times to conduct [dredge and fill] activities" (Peters et al. 1995, p. 4). The authors conclude that from the perspective of larval and early juvenile fish, dredging projects would have less impact if conducted in the late fall than during the late winter or early spring.

More recent research by biologists with the NOAA and the Corps has identified over 100 species of larval fish in or around Beaufort Inlet (L. Settle, NOAA, and H. Heine, USACE, pers. comm., October 18, 2002). The concentrations of larvae in the water column are such that the comparably low volume of water entrained by a 30 inch dredge in Beaufort Inlet is insignificant when compared to the tidal prism of the inlet. Thus the potential impacts to larval fish from dredge and fill projects appears to be insignificant.

In surveys of potential dredge sites offshore Bogue Banks, Peterson and Wells (2000) identified an average of 16,531 to 37,149 individuals per km^2 in the November 1999 survey, 1,087 to 9,882 per km^2 in February 2000 and 488 to 120,536 per km^2 in May 2000. Over half of the total catch in the November 1999 sampling were of spot (*Leiostomus xanthurus*), with pinfish (*Lagodon rhomboides*), pigfish (*Orthospristis chrysotera*) and croacker the next most common species in the offshore sampling area. The inshore sampling area was dominated by croaker (*Micropogonias undulatus*), silver perch (*Bairdiella chyrsoura*), silversides (*Menidia menidia*), pinfish and sea mullet *(Menticirrhus* sp.). Altogether 51 fishery species were found during the three survey periods, and fish gut content analyses indicate that the fish are using the invertebrates present in or on the seabed as a food source. The researchers concluded that "dredging could impact the demersal fishes and crustaceans by direct removal and mortality during dredging, by causing emigration to other areas, where crowding could reduce growth and production, and by creating some unknown period of time when benthic prey abundances had not yet recovered and so growth and production were reduced" (Peterson and Wells 2000, p. 9). In addition, if the dredging alters the sediments exposed on the seabed, the benthic invertebrate community may be changed and less food could be available to fishery resources than prior to the dredging.

In the same offshore and nearshore areas proposed for dredging, Coastal Science Associates (2002) conducted biological surveys of the macrobenthic fauna in June and November 2001. Species diversity ranged from 3.60 to 4.61 at the dredge sites and 3.88 to 4.72 at control sites. November densities were lower than those measured in June. Beach seines were used to sample surf zone fish along Bogue Banks, with 7 species caught in the June sampling period and 4 in the November sampling period. The more recent (November 2001) survey found highly variable species and numbers between stations but overall caught silverside, striped mullet (*Mugil cephalus*), summer flounder (*Paralichthys dentatus*) and Florida pompano (in order of decreasing abundance). Gut content analyses of 10% of the fish caught in beach seines indicate that coquina clams are the dominant food source, with mole crabs and silverside minnows also serving as prey.

Researchers at IMS-UNC conducted beach seine surveys during August 2002 along Bogue Banks, several months after Phase I of the locally-built beach fill project was completed (C.H. Peterson, IMS-UNC, unpubl. data, Appendix G). The seines were towed parallel to the beach, approximately 40 m from shore, simultaneously at beach fill and control sites. Three tows were conducted at each of 12 sites (6 control and 6 nourished). The average number of pompano and sea mullet caught at the control sites was slightly higher than the average number at nourished sites. The number of flounder and silverside did not differ between control and nourished locations. The average number of anchovy and menhaden captured at the nourished sites was much higher at nourished sites than control sites, however, differing by an order of magnitude. Additional fish surveys are scheduled for this fall (G.A. Johnson, IMS-UNC, pers. comm., September 11, 2002), which should provide additional data for determining if the beach fill project has negatively or positively impacted surf zone fish.

Since Florida pompano is regularly found along the beaches of Bogue Banks, scientists at IMS-UNC have held experiments to test the foraging ability of Florida pompano (*Trachinotus carolinus*) in various turbidity and shell environments that simulate field measurements taken during and after beach fill projects. One set of experiments replicated turbidity levels measured in the field following dredge disposal events on North Topsail Beach, and documented a 40.5% reduction in Florida pompano (a visual feeder) predation of coquina clams and 30% reduction on mole crabs (Lindquist and Manning 2001). Thus the turbidity created by a beach fill project can significantly reduce the foraging ability of at least one species of surf zone fish.

Experiments with coquina clams and pompano given various shell percentages (4:1, 2:1, and 1:1 shell:quartz sand ratios and quartz sand only with no shells) show that the foraging efficiency of the pompano also decrease with increasing shell content, with a statistically significant decline ($P<0.05$) between 0 and 50% or greater shell content (L. Manning, IMS-UNC, unpubl. data, Appendix G). The preliminary data from the IMS-UNC monitoring of the recent beach fill project on Bogue Banks, combined with this experimental data, suggest that recovery of indicator infauna species (and their predators such as Florida pompano) may be delayed by large increases in shell material within beach fill sediments. As a result, sediment compatibility with native beach sediments in the project area is a significant concern.

In addition to these studies within the project area, the recent beach fill project in New Jersey has been monitored for fishery impacts (Wilber 2001). The offshore fish species in this study consisted of winter flounder (*Pleuronectes americanus*), summer flounder (*Paralichthys dentatus*) and scup *(Stenotomus chrysops*). The presence of rock groins in the project area makes this study area different than Bogue Banks, but some of the surf zone fish species are the same (silversides). Bluefish (*Pomatomus saltatrix*) and northern kingfish (*Menticirrhus saxatilis*) were the other dominant fishes found in the New Jersey surf zone surveys. Prior to the beach fill project, the bluefish and silverside were captured more often near the groins, but after the project (when the groins were buried partially) these numbers decreased. "Kingfish abundances were significantly higher at beach nourishment sites than at reference stations, whereas, bluefish were more abundant in the reference area at the time of beach nourishment" (Wilber 2001). The distribution of silversides was the same at nourished and control sites, and the differences in bluefish and kingfish were not detectable 1 to 2 years following the beach fill placement. Gut content analyses of the fish "did not reveal any evidence that benthic prey availability was reduced by the beach nourishment project" (Wilber 2001).

Potential Impacts to Birds

North Carolina is along the Atlantic flyway for migratory birds, and the orientation and location of Bogue Banks in relation to Cape Lookout creates a situation where seabirds, shorebirds, colonial waterbirds and songbirds are all present in varying numbers throughout the year. Recent research has focused on the sensitivity of waterbirds to human disturbance, mammalian predators, and wetland foraging habitats.

Rodgers and Smith (1995) found that colonial waterbird nests are sensitive to human disturbance, and more sensitive to pedestrians approaching a nest than a motorboat. Experiments conducted by the researchers determined that wading bird colonies need a 100 m buffer and mixed tern and black skimmer colonies need a 180 m buffer. The terns and skimmers are more sensitive than other wading birds, leaving nests and taking flight with less provocation. Therefore if the Bogue Banks project proposes to work near a waterbird colony, these buffers serve as a guideline for setback distances for work areas to avoid significant impacts to the colony.

Erwin et al. (2001) surveyed the interaction between ground-nesting waterbirds and mammalian predators on the barrier islands of eastern Virginia. The range of the key mammalian carnivores (i.e., red fox (*Vulpes vulpes*) and raccoon (*Procyon lotor*)) has increased from 1975 to 1998, and the number of nesting waterbird colonies has decreased. The waterbird populations for common terns (*Sterna hirundo*), gull-billed terns (*S. nilotica*), royal terns (*S. maxima*) and black skimmers have "decreased dramatically," which the authors largely attribute to mammalian predation. Sandwich (*S. sandvicensis*) and least terns (*S. antillarum*) showed marginal population changes. The authors recommend the creation of dredged material islands as an alternative nesting and roosting habitat devoid of mammalian predators.

Moist soil substrates, such as bayside tidal flats or pools, are very important foraging habitat for nesting piping plovers (*Charadrius melodus*) and have been found to be preferential habitat for nest site selection (Fraser 2001). Unvegetated mud flats, sand flats and tidal pools are highly used by piping plovers during overwintering periods as well and may be essential for migratory juveniles. Prior to fledging, chicks that have access to these habitats may have higher survival rates compared to chicks without such foraging habitats. Twenty-two other shorebird and waterbird species have been documented to use the same moist substrate foraging habitats (Fraser 2001). Collazo (2001) also identified accessibility to wetland foraging habitat as a key variable in predicting shorebird abundance.

The Corps has sponsored monitoring of shorebirds and waterbirds in Brunswick County as part of two beach fill/disposal projects (the Ocean Isle hurricane protection and the Wilmington Harbor expansion projects). CZR (2002a) summarized the first year of monitoring at Ocean Isle following beach fill construction during the winter of 2000-2001. These surveys identified 29 species of waterbirds (peaking in abundance during the November fall migration period) and 17 species of shorebirds (also peaking during the fall migration) using the study area. The birds preferred the intertidal habitats in the survey area, spending three-quarters of the survey observations in those moist soil substrates. Nesting was attempted by Wilson's plover, American oystercatcher and willet during 2001 but none of the nests were successful; all of the nesting occurred near Shallotte Inlet, which also served as the dredge site for the beach fill. CZR (2002a) concluded that although there was a statistically significant difference in waterbird abundance between nourished and non-nourished areas, the absence of pre-project baseline data preclude an assessment of whether this was an effect of the beach fill or not. There were no significant differences in shorebird abundance or species richness detected. Piping plovers were observed in the study area during the spring and fall migration periods.

CZR (2002b) summarized similar avian monitoring at Holden Beach, Oak Island, Caswell Beach and Bald Head Island following the first year of dredge disposal from the Wilmington Harbor expansion project. The researchers concluded that the data were not sufficient yet to determine if the beach fill had impacted waterbirds or shorebirds. Both CZR (2002a) and CZR (2002b) found that the birds preferred inlet areas to oceanfront beach areas.

Potential Impacts to Sea Turtles

Two recent studies from Florida have added longer-term data on potential impacts to sea turtles from beach fill projects. Ernest (2001) monitored sea turtle nesting productivity on nourished and control beaches on Hutchinson Island, Florida, for three years. This study found that although the number of turtles emerging from the ocean to nest did not differ between nourished and non-nourished beaches, the number of nests as compared to false crawls decreased on the nourished beaches. The lower nesting success was documented on nourished beaches that were tilled and those that were not tilled, suggesting that compaction of the beach fill material was not the only determining factor in nest site selection. Those sea turtles that did nest used the entire beach width for nesting, often placing nests nearer the ocean on nourished beaches than on non-nourished beaches, increasing the risk for flooding and washouts as the beach fill equilibrated following initial placement Ernest (2001) concluded that the "nourished beaches were generally more compact, wetter, coarser and warmer than those of control and pre-nourished beaches. Tilling significantly reduced compaction levels and effectively eliminated the impacts of high compaction (>500 psi) on the frequency of abandoned digs and the time required by turtles to excavate an egg chamber. The warmer sands of nourished treatments significantly reduced incubation periods and may have contributed to a higher incidence of late-stage embryonic mortality. However, despite changes in the incubation environment there were no significant differences in overall reproductive success."

Ernest (2001) recommends that impacts to sea turtles may be minimized if: (1) the beach fill is compatible with native sediments; (2) a more natural fill template is used; (3) adequate tilling is conducted; (4) nests laid on the seaward portion of the nourished beach are protected from washing out; (5) alternative methods of placing fill (e.g., stockpiling) be evaluated; and (6) monitoring programs distinguish impacts by utilizing baselines and controls.

Steinitz et al. (1998) conducted the first long-term (7 year) study of sea turtle nesting on nourished beaches in Florida. They found no significant difference in the successful hatching of eggs deposited on nourished beaches as opposed to adjacent non-nourished beaches. The number of nests deposited by nesting females was significantly lower on nourished beaches than the control beach, however. "Abandoned nesting attempts were positively correlated with the greater surface hardness of the renourished beach" for the first two years following nourishment, but nesting attempts were more successful with time as the surface hardness decreased. Over time as the nourished beach eroded to a narrower width, nesting densities again declined. "Thus, at Jupiter Island [Florida], less nesting occurred on renourished beaches because these sites cycled between relatively long and unattractive, and relatively short and attractive, 'states'" and "to the extent that other renourished beaches mimic these cycles, they also represent inferior nesting habitats" (Steinitz et al. 1998, p. 1000).

These studies indicate that there may be long-term impacts to nesting sea turtles resulting from beach fill projects. Recent experience with the local beach fill project, and the sensitivity of nesting sea turtles to the altered beach materials (i.e., more shells and a darker color), is being monitored. The first phase of this project used a hopper dredge to dredge seabed sediments for the beach fill. Unfortunately the hopper dredge sucked up 5 sea turtles, killing 4 of them, during periods when the water was warmer than 57 degrees Fahrenheit (in December 2001 and April 2002). Both Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) sea turtles were killed.

In summary, dredge and fill projects may cause significant ecological impacts at the dredge sites and to the variety of microhabitats found on the beach in the placement area. The impacts may last for a few months to several years depending on the timing of the construction, how the dredging and fill placement are conducted, and the compatibility of the fill material with the natural beach sediments and newly exposed sediments in the dredged pits. Some of the ecological impacts may be avoided and others may be minimized with existing technologies and practices.

SECTION 9. COMPARISON OF IMPACTS

The Service has previously summarized the comparative impacts of shoreline stabilization alternatives in USFWS (1999), USFWS (2000a), USFWS (2000b), USFWS (2001) and USFWS (2002a). These reports are incorporated here by reference. If hard stabilization alternatives (jetties, groins, seawalls, revetments, breakwaters, etc.) are developed, this section will require supplemental material.

The potential impacts of dredge and fill projects vary with several factors. These factors include the timing of the dredge and fill activities, the construction methodology, design template, sediment compatibility, and best management practices employed. The ecological impacts of these projects can be avoided and minimized with existing technologies and practices. This section summarizes project features that would avoid and minimize potential adverse impacts in the Bogue Banks project area.

First, the timing of project construction and renourishment (or maintenance) episodes is crucial to avoiding impacts to some species and minimizing impacts to others. If hopper dredges are to be used, dredging should be limited to periods when the waters are less than 57 degrees Fahrenheit to avoid sea turtles in the dredging areas. This period is generally late December through early April in the Bogue Banks area. If inlet areas are targeted as a sediment source or are immediately adjacent to beach fill areas, periods of peak larval and early juvenile fish presence should be avoided by dredging in the late fall rather than late winter and early spring. Beach fill placement should occur during periods of lowest invertebrate abundances on the beach, or between December and March for Bogue Banks. Migratory bird use peaks in early spring, with the nesting season for several species starting in March. Sea turtles nest in the project area from May 1 through November 15. The West Indian manatee (*Trichechus manatus*) may be present in project waters from June through the end of October. Local harvest of surf zone fisheries is conducted on the beach during the late fall. Fishing tournaments occur in the nearshore and offshore areas between June and November.

Reconciling these periods of biological productivity, impacts would be avoided and minimized the greatest if sediments sources were not located in inlets, beach fill does not occur adjacent to an inlet where end losses may be higher (e.g., the Bogue Banks Beach Restoration Project avoided the ~1 mile of beach closest to Bogue Inlet; CSE 2001), and construction is limited to the period between December and March 1. The actual start date may be determined by real-time monitoring of water temperatures and demersal fish and shrimp abundances in the targeted dredging area. The actual zone of influence of Bogue and Beaufort Inlets on adjacent shorelines should be assessed by the North Carolina Coastal Resources Commission's Science Panel on Coastal Hazards, which is formulating a methodology and specific data on other tidal inlets in the state.

The timing of maintenance episodes is one of the most critical factors determining the longevity of ecological impacts. Studies conducted at North Topsail Beach and Bogue Banks indicate that a one year interval between disposal or beach scraping episodes does not allow the sandy beach ecosystem to fully recover (Lindquist and Manning 2001, Peterson and Manning 2001, Peterson et al. 2000). Another study has found that a three year interval is not sufficient for full recovery at Pea Island (Donoghue 1999). More frequent fill activities increase the interannual variability of sea turtle habitat available for nesting (Steinitz et al. 1998), which typically fluctuates on a natural 3 year cycle. Therefore a maintenance (or renourishment) interval longer than 3 years would allow the greatest level of recovery of the ecosystem between episodes, avoiding a long-term or permanent loss of biological productivity in the fill area.

Secondly, the construction methodology influences the level of ecological impacts. Hopper dredges were already discussed for their known impact on entraining and killing sea turtles in the project area. While cutterhead dredges do not have the same impact on sea turtles, they do tend to dredge deeper cuts at the dredge site than hopper or dustpan dredges. In general, shallower cuts allow for faster recovery of the benthos than deeper cuts that may become stagnant and inhospitable to the pre-project benthic community (C-CORE 1996, MMS 2001).

Regardless of the dredge type, the methods used in excavating the sediments influence the recovery of the benthic ecosystem. Muddy and silty areas should be avoided to minimize turbidity caused by the dredging and any anoxic pore waters within the seabed. The area dredged for each fill episode should not be re-used until the seabed has fully recovered its community structure; in other words, the initial construction should dredge one area of the dredge site and the first maintenance episode should dredge a different area, etc. Side slopes in the dredge pits should be as gentle as possible, not leaving steep sidewalls that may slump and bury benthic infauna at a later date. The excavation cuts should not expose dissimilar sediments than what was present prior to dredging in order to facilitate recovery of the same community structure post-dredging (e.g., Peterson and Wells 2000, C-CORE 1996, MMS 2001). Leaving isolated pockets or "islands" of undisturbed seabed may also encourage quicker recovery of the benthic community after dredging (Hobbs 2002). Finally, barge overflows should be avoided so turbidity plumes and density currents are not generated. If economic loading is a preferred construction method, then on-board processing and dewatering techniques with directed subsurface discharge should be evaluated (see C-CORE 1996).

The design template also affects the magnitude and duration of ecological impacts. Longer projects tend to have more ecological impacts than shorter ones. Invertebrate species without pelagic larval stages depend upon gradual recolonization of the beach fill from the edges in. Shorter projects should recover more quickly than longer projects. The 24 mile long project area on Bogue Banks creates a situation where long sections of beach fill are likely to be designed. Dividing the beach fill into 3 or 4 sections, and constructing those sections in a non-contiguous fashion, should facilitate infaunal recovery of each individual section. If the maintenance or renourishment interval is once every 8 years, for instance, the project area could be divided into four sections of 5.25 miles each (avoiding up to 1.5 miles adjacent to each inlet). The four sections could be constructed on an alternating schedule of one every 2 years, with no two consecutive construction episodes contiguous to each other. The locally funded beach fill project is being constructed in three sections on a 10 year maintenance interval, but the three sections are being constructed in a contiguous sequence over an initial 3 year period.

The inclusion of a dune ridge or levee within the design template also poses potential ecological impacts. Bogue Banks has a high interior elevation with several relict dune ridges. The back portion of the oceanfront beach is typically backed by a steep dune scarp with very few breaches. The dune scarp has frequently been fronted by piles of sand pushed by bulldozers or trapped by sand fencing and planted vegetation. These existing activities impact the vegetation and the ghost crab population (Nordstrom 2001, Nordstrom 1994, Peterson et al. 2000), and incorporation of similar activities on a larger scale by including a dune ridge in the design template may increase the scale and duration of these impacts. Instead, ecological impacts may be minimized by utilizing the existing dune face into the design template. Sand fencing and planting diverse vegetation species in a more natural, random design (not rows) would have less ecological impact by allowing natural processes to form a foredune seaward of the dune scarp. The plantings could include seabeach amaranth, sea oats, bitter panicum and other species propagated from local stock in the Brunswick County facilities currently growing plants for beach use. Spacing the plants in an irregular pattern may provide nesting and shelter habitat for some shorebirds as well. Thus by capitalizing on natural processes, a potentially adverse design feature could become an environmental enhancement feature.

The fourth project feature that dictates the magnitude and duration of ecological impacts is sediment compatibility. When fill sediments closely match the native beach sediments in color, size and content (shell versus quartz), the beach ecosystem typically recovers in less than 8 months. If the material differs from the native sands, though, full recovery may not be detected prior to the next fill episode and the impacts may become permanent. Natural beaches in North Carolina have on average less than 4% silt and clay content, for instance. Fill material that includes higher silt and clay content has significant ecological impacts on sandy beach infauna and foraging fish (e.g., Lindquist and Manning 2001, Peterson et al. 2000, Peterson and Manning 2001). The locally funded beach fill project introduced excessive amounts of shell material to the beaches. Key indicator invertebrate species and foraging fish are sensitive to increased shell content (Lindquist and Manning 2001; L. Manning, IMS-UNC, unpubl. data, Appendix G) and recovery of these beaches is likely to take longer than the norm.

If the proposed federal project uses sediment that more closely matches the native sands of Bogue Banks than the locally funded project, the recovery of the beach ecosystem should be more rapid than that of the local project. Preliminary investigations of potential sediment sources indicates that such sediments are likely to be found in the inlets and the nearshore and offshore disposal areas. Bogue Inlet and Bogue Sound are high value resource areas and should be avoided as sediment sources for that reason. Archaeological resources in Beaufort Inlet indicate it should be avoided as a sediment source as well. The nearshore and offshore marine areas are also of high resource value, but they contain areas previously disturbed (the nearshore and offshore disposal areas). Targeting the nearshore and offshore disposal sites as a sediment source(s) would limit any disturbance to areas already disturbed by dredging activities. The deposition of material at these sites from dredging of the Morehead City navigational channel system may have already sorted undesirable material (silts and clays) from the dredged material. Thus these two areas may contain ecologically compatible beach fill material, and dredging of such material would avoid additional seabed disturbances to an area that has high resource value.

Targeting the nearshore and offshore dredged material disposal sites as a sediment source would also allow for best management practices to be incorporated into the project, limiting overall impacts to the Bogue Banks ecosystem. Maintenance dredging of the navigational channels in Beaufort and Bogue Inlets, the AIWW and the Morehead City port will continue without the project. As the dredging continues, the nearshore and offshore disposal sites will approach capacity and new sites will be needed. If the beach fill project recycles material from the dredged material sites, however, the capacity of the dredged material disposal sites will be increased. New offshore dredged material sites may be avoided, minimizing long-term and cumulative impacts to the high value seabeds of the project area. Recycling of this material to the beaches of Bogue Banks reintroduces it into the littoral system (defined in this report as the beach, surf zone and inlets) and offsets any erosional losses or shoreline fluctuations resulting from inlet dredging.

Another best management practice expands this regional sediment management approach to include the beach disposal operations at Atlantic Beach and the potential Section 933 project on Pine Knoll Shores and Indian Beach. A new federal beach fill project on Bogue Banks should incorporate these dredge disposal activities into this project, modifying the design template of the dredge disposal to meet the template of the beach fill project. The length of new (federal) work would be minimized, and consequently the frequency of ecological impacts would be reduced (i.e., not having two projects placing sediments on the same beaches of Atlantic Beach and/or Pine Knoll Shores). Incorporation of the dredge disposal operations into the storm damage reduction project design would also reduce the total amount of fill material necessary for dredging from offshore areas, which in turn would minimize the spatial scale of ecological impacts to benthic communities.

Lastly, known fishing grounds should be avoided as sediment sources to minimize impacts to fishery resources and the recreational and commercial fishing industry. These areas should be delineated via a thorough survey of recreational and commercial fishermen in the area. The North Carolina chart book can serve as a preliminary guide on advertised fishing grounds in the project area (GMCO 2001). Possible fishing grounds are indicated along the Cape Lookout shoals, the western side of Cape Lookout, at several artificial reefs and shipwrecks, at two locations along the Beaufort Inlet navigational channel and at the hardbottom areas south of Emerald Isle.

The first of the two fishing grounds near the navigational channel is advertised for king mackerel (*Scomberomorus cavalla*) and is found approximately half a mile landward of the seaward end of the navigational channel and overlapping the offshore dredged material site (in 14 to 40 feet of water). The second site is much larger, advertised for king mackerel and dolphin (*Coryphaena hippurus*), and starts just seaward of the last buoy marking the alignment of the navigational channel in 57 to 90 feet of water depth. Smaller areas within this large fishing grounds area include those known as “Northwest Places,” “Little 10 Fathom,” and “Big 10 Fathom.” Finally, the hardbottom areas offshore western Bogue Banks contain a fishing ground known as “45 Minute Rock” that is advertised for dolphin, sailfish (*Istiophorus platypterus*), king mackerel, and cobia (*Rachycentron canadus*). This area extends from roughly 56 to 67 feet of water depth.

For environmental impacts that are unavoidable and have been minimized to the extent feasible, mitigation measures may offset the adverse impacts. Impacts resulting from turbidity levels that exceed ambient levels, for instance, may be minimized by avoiding dredging muddy sediments, but not all of the turbidity can be avoided. As the beach fill dewaters (the slurry is 80-85% water and only 15-20% sediment), turbidity levels in the surf zone increase. If the fill material contains muddy or very fine-grained sediments, reworking of the fill by waves may elevate turbidity levels in the surf zone for extended periods of time (e.g., Appendix G). One measure that should minimize turbidity at the dredge site is to continuously monitor turbidity levels and stop dredging when the state saltwater quality standard of 25 NTUs is exceeded. If the background turbidity levels are less than 10 NTUs, though, water quality will be degraded while construction continues at the 25 NTU level. Furthermore, large dredge and fill projects that involve annual dredging and fill activities could increase a normally temporary impact to a persistent one.

If elevated turbidity levels are anticipated to be persistent, either as a result of reworked fill material or annual construction schedules, compensatory mitigation for water quality impacts should be implemented to offset the degradation to water quality. This can be done through the construction of oyster reefs, which are known for their water filtering capabilities. Although the oyster reefs would require placement within the estuaries of the project area, and are therefore not in the immediate vicinity of the impact area (the surf zone and the offshore dredge site), this difference can be compensated for by appropriate mitigation ratios for out-of-kind mitigation.

The many high value habitats within the project area call for no net loss of in-kind habitat value by the Service's Mitigation Policy. Avoiding dredging in Bogue Sound, Bogue Inlet and new areas of the nearshore and offshore marine areas should result in no net loss of habitat value. Avoiding construction of a bulldozed dune ridge or dike, and utilizing natural windblown processes and vegetation should result in no net loss to island interior habitats. Beaufort Inlet has a high to medium value, which calls for no net loss of habitat value while minimizing the loss of in-kind habitat value. Utilizing existing dredged material excavated from Beaufort Inlet and associated navigational channels should minimize any loss of in-kind habitat value. Recycling ecologically compatible materials from the nearshore and offshore disposal sites would also minimize the loss of new, undisturbed seabeds and potentially restore habitat value to these sites by returning them to a more natural bathymetry. The oceanfront beach proposed for fill placement has medium to low habitat value, and the mitigation goal for this resource category is to minimize loss of habitat value. Scheduling construction during periods of lower biological activity, using ecologically compatible fill material and breaking the project area into several shorter sections that receive fill on a rotating schedule should minimize the loss in habitat value for the oceanfront beaches. Additional protection measures for preserving habitat value include prohibiting or severely restricting beach scraping in between construction episodes and prohibiting beach driving during the sea turtle nesting season (beach driving is currently allowed starting in early September while turtle nests are still incubating).

Finally, although the scientific data on ecological impacts of dredge and fill projects has improved, biological monitoring continues to be a useful management tool. MMS (2001) recommends that an advisory team be convened to provide an adaptive management strategy as the biological and physical monitoring studies are finalized, initiated and completed. In this way modifications to study designs will ensure specific scientific questions are answered and spurious costs are avoided. If recovery is documented early in the project, then monitoring may be discontinued for the rest of the project's lifespan.

A threshold for recovery should be agreed to by an advisory team composed of the Corps, resource agencies, and the local sponsor prior to project construction. MMS (2001) recommends that recovery should be assumed when 95% of the mean values of species abundance, total biomass and estimated secondary production have returned to a particular site as compared to control sites. Depending on the longevity, size and frequency of impacts, other recovery thresholds may be appropriate. The Corps' recent New Jersey monitoring efforts utilized statistical techniques to determine when recovery was reached for abundance, biomass and taxa richness parameters (USACE 2001).

Monitoring should be conducted pre-construction, during construction, and post-construction until the pre-determined recovery threshold is reached. Maintenance events should reinitiate monitoring until the recovery threshold is again reached. At five year intervals the need for post-maintenance monitoring should be re-evaluated. Rates of recovery can be estimated by computing the rates at which means from fill and control areas converge (MMS 2001).

SECTION 10. CONSERVATION MEASURES AND RECOMMENDATIONS

The Service has previously summarized conservation measures that could be incorporated into an artificial beach and dune construction project in USFWS (1999), USFWS (2000a), USFWS (2000b), USFWS (2001) and USFWS (2002a). These reports are incorporated here by reference, and this section will focus on new findings not included in previous reports. The conservation measures are organized so that measures that would avoid adverse ecological impacts are presented first. Measures to minimize adverse impacts that are not avoidable are then described. Finally, compensatory mitigation options are summarized, utilizing the resource category determinations outlined in Section 6 and the Service's Mitigation Policy to suggest potential mitigation measures. Recommendations for these conservation measures are offered following the relevant conservation measures.

Measures to Avoid Ecological Impacts

There are several features of a beach fill design that potentially avoid adverse impacts to ecological resources. In general, the shorter the length of beach fill, the less the environmental impact. Avoiding placement of fill in areas close to inlets will limit indirect impacts of unwanted shoaling within navigation channels. The preliminary findings of the North Carolina Coastal Resources Commission (CRC) Science Panel on Coastal Hazards is that North Carolina inlets tend to influence oceanfront erosion and accretion for a mile or more on either side of the inlet. Beach fill placed in these areas is likely to be lost more quickly than in other areas and to alter the tidal currents and shoals in the adjacent inlet. While additional shoaling in some inlets may be beneficial to avian and fishery resources using the inlet, the subsequent increase in maintenance dredging and disposal may harm those resources more frequently and persistently. Therefore the Service recommends that:

1) The beach fill template should concentrate on areas more than approximately one mile from Bogue and Beaufort Inlets.

The inclusion of artificial dunes or levees in the beach fill design increases the ecological impact of a potential project. Bogue Banks is a sand-rich island with some of the highest and most massive dune fields in the state. Creation of new dunes or levees is not likely to appreciably increase the storm protection to structures. Bulldozing or beach scraping to build artificial dunes or levees adversely impacts the macroinvertebrate community of the oceanfront beach (Peterson et al. 2000; Peterson and Manning 2001). Avoiding extensive construction activities on the landward portion of the beach reduces the disturbance to ghost crab and sea turtle nesting habitat. Not constructing an artificial dune or levee would also avoid disturbance to the vegetative community present on the existing dunes, which provide foraging habitat and shelter to numerous terrestrial and avian fauna. Landscaping artificially constructed dunes or levees with nursery-raised dune grasses often establishes a monoculture with the aesthetic appearance of a cultivated field rather than the irregular and patchy distribution of natural pioneering plants. Therefore, we recommend:

2) The beach fill template should capitalize on natural processes and the existing dune system, and thereby avoid impacts to the natural dune community by incorporating sand fencing and diverse native vegetation in an irregular planting pattern. This would restore a foredune to the natural dune system of Bogue Banks instead of constructing an artificial dune.

In addition to measures that avoid indirect impacts to adjacent inlets and the dune system on Bogue Banks, the potential project could avoid impacts to offshore marine activities as well. There are currently 10 active and 33 inactive dredged material islands in the project area. Totaling ~387 acres, the dredged material islands represent an unknown quantity of sandy material that is likely to be ecologically compatible with the native oceanfront beaches of Bogue Banks. Over time as these dredged material islands become more vegetated and stabilized, their value to nesting shorebirds and colonies of waterbirds reduces as bare ground is lost and predators are introduced. These islands are also unnaturally sited within Bogue Sound, the White Oak River and Newport River estuaries. Selective removal of material from some of these dredged material islands could potentially restore estuarine fishery habitat and bare ground bird nesting areas. The capacity of the dredged material islands then increases for maintenance dredging disposal, and the islands could potentially be maintained in an early successional state that maximizes avian usage. Positive ecological benefits may result and offshore marine habitats would be avoided and undisturbed. Thus the Service recommends that:

3) The 43 dredged material islands within the project area should be considered as a sediment source, with associated positive ecological benefits of restoration incorporated into the economic cost and benefit analysis for this source.

Another avoidance measure would be to avoid dredging sediment from areas of high ecological value as defined in Section 5. Bogue Sound and Bogue Inlet are two such areas within the project area. Both of these areas are comparably undisturbed to similar habitats in North Carolina, and both generate significant commercial fish landings and recreational opportunities to the public. Direct impacts to fishery and avian resources can be avoided if no sediment dredging occurs within the natural habitats within Bogue Sound and Bogue Inlet. The integrity of the Bogue Inlet complex for migratory birds and larval fishery resources would be preserved. As a consequence, significant ecological impacts can be avoided if:

4) Bogue Inlet and natural areas within Bogue Sound are not used as a sediment source.

Bogue Banks supports one of few known commercial harvests of fishery resources on the oceanfront beach, a tradition with local residents. Heavy equipment on the beach and active pumping of beach fill during the annual harvest by these fishermen is likely to hamper or prevent their harvest and economic livelihood. The seasonality of this harvest indicates a period of high biological productivity in the surf zone of the project area, and a secondary benefit to avoiding conflicts between local fishermen and dredge equipment would be to avoid impacting the migratory fishery stocks present during that time. Therefore the Service recommends that the potential shore protection project:

5) Avoid construction during the fall season when local commercial fishermen are harvesting fish from the beach.

The Bogue Banks area also supports several fishing tournaments every year that attract national and international participants. These tournaments target King mackerel, Spanish mackerel, wahoo, tuna, dolphin, spotted seatrout, and blue marlin. Dredging equipment offshore would limit the area available for tournament participants to target. The operation of the dredging equipment would have an unknown acoustic effect on the sought-after migratory fish species and their prey. Local tournaments were scheduled during every month between June and November during 2001, usually for one week each. The high recreational value of these tournaments suggests that direct and indirect impacts to the tournaments and their sponsors could be avoided by not dredging offshore areas during those periods. Thus the Service recommends that:

6) Offshore marine dredging for beach fill sediment should not be conducted during periods of scheduled fish tournaments, typically the months of June to November.

Approximately seven miles of oceanfront beach in Atlantic Beach already receive dredged material from maintenance dredging of the Morehead City/State Port navigational channel on a periodic basis. As a result this oceanfront beach is already stabilized and the ecological community on its beaches disturbed every 6 to 8 years. Additional disturbances to this section of beach could be avoided if the Bogue Banks Shore Protection Study incorporates this existing dredged material disposal into the beach template for the island. The template for the dredge disposal could be modified to conform with the preferred template for the other sections of the island instead of placing additional fill in Atlantic Beach. If the dredged material pumpout on Atlantic Beach receives 50 cy/ft of beach, for example, but the shore protection project calls for 100 cy/ft of fill, then the dredged material project should be modified to a 100 cy/ft design template. In other words, development of consistent plans between the two projects would avoid ecological impacts resulting from a higher frequency of disturbance to beaches in Atlantic Beach (both projects alternately disturbing the same beach sections). Therefore, the Service recommends:

7) The dredged material disposal already occurring on the oceanfront beaches of Atlantic Beach should be modified to conform with the preferred design template instead of construction and maintenance of two separate projects in this area.

Finally, the potential beach fill project could avoid ecological impacts if it follows the purpose and intent of the Coastal Barrier Resources Act (CBRA). Several areas within the project area, most notably Hammocks Beach State Park, Fort Macon State Park and Shackleford Banks, have been designated as Otherwise Protected Areas (OPA) under the CBRA. While the only prohibition on federal expenditures within an OPA pertains to the National Flood Insurance Program (NFIP), the Service encourages federal activities within OPAs to preserve the integrity of the CBRA. Thus we recommend that:

8) Dredging of beach fill material should not occur within an OPA for placement outside of that OPA. Beach fill activities within an OPA should reduce federal expenditures, protect

fish and wildlife resources, and protect life and property.

Measures to Minimize Ecological Impacts

For those impacts that cannot be avoided, several options may minimize the scope and degree of the ecological impacts. For instance, fill material placed on the beach should match the native beach sediments in mineralogy, color, grain size distribution, grain shape or maturity, and compaction (or porosity). Macroinvertebrate infauna such as mole crabs and coquina clams are substrate sensitive, preferring certain grain size distributions and their corresponding geomorphic expressions (Alexander et al. 1993; Bowman and Dolan 1985; Donoghue 1999; Lindquist and Manning 2001; Peterson and Manning 2001). The potential impacts to sea turtle nests incubating in the new fill have been previously described (e.g., USFWS 2000a); successful incubation depends upon the moisture content, porosity, and mineralogical content of the beach fill material. Matching the fill sediments to the native sediments also preserves the aesthetic value and recreational experience of visitors to the new beach. Recovery times for fish and wildlife resources should be minimized if:

9) Sediment dredged for placement on the beach should be compatible with the native sediments of Bogue Banks.

The ~24 mile long oceanfront project area along Bogue Banks is the longest in North Carolina under consideration for an artificial beach fill project. The Dare County Beaches (Bodie Island Portion) Project divided its 14.2 mile length into three segments. Alternating construction amongst the three segments will minimize ecological impacts by limiting the length of beach affected in any given construction cycle. Assuming sections of beach influenced by adjacent inlets will be avoided, approximately 24 miles of Bogue Banks beaches could be directly impacted by fill placement and manipulation by heavy equipment. Division of this record length into four segments could minimize impacts if they are filled on a rotating schedule. Segments adjacent to each other should not be constructed consecutively, allowing for the quicker recovery of beach fauna because adjacent, undisturbed areas would be available for recruitment to the new fill. Therefore, the Service recommends that:

10) The 24 mile long Bogue Banks oceanfront shoreline could be divided into four sections that are constructed on a rotating schedule with adjacent sections constructed non-consecutively.

Impacts to sea turtles can be minimized by avoiding periods of highest use of the project area by these federally-protected fauna. If hopper dredges are used as part of the construction, they have the potential to take sea turtles when they are in the waters of the project area. Similarly, construction on the beach has the potential to take nesting sea turtles during warmer months when sea turtles are nesting, incubating and hatching on Bogue Banks beaches. Leatherback sea turtles (*Dermochelys coriacea*) have nested at Cape Lookout and Cape Hatteras National Seashore in recent years and during earlier months (e.g., April) than the more common loggerhead sea turtles (*Caretta caretta*). Consequently, we recommend that:

11) The construction schedule avoid using hopper dredges when waters exceed 11 degrees Celsius and avoid construction activities on the beach during the sea turtle nesting and hatching season (April 15 through November 15 annually).

Longer recurrence intervals between fill episodes (often referred to as “renourishment”) minimize ecological impacts by allowing greater recovery times for fish and wildlife resources in the project area. The long-term resilience of coastal fauna to large-scale beach fill projects is unknown, but scientific findings so far suggest a one to three year interval is not sufficient in North Carolina (Donoghue 1999; Lindquist and Manning 2001). The comparably low erosion rates on Bogue Banks indicate that the maintenance interval will be longer than the standard 3 to 5 year cycle utilized for federal shore protection projects at Wrightsville Beach, Carolina Beach, and Kure Beach. The frequency of dredge disposal in Atlantic Beach is double that of these other Corps projects. Therefore the Service urges the Corps’ project team to consider:

12) The maintenance construction, or renourishment interval, should be greater than three years.

Some portions of the offshore marine area have already been disturbed by dredging of navigational channels and disposal of dredge material. An offshore and a nearshore disposal area have been constructed off of Beaufort Inlet in the project area. While the ecological function and value of these offshore disposal areas is not readily known, they are artificial habitats not natural to the project area. The disposal sites are periodically disturbed by additional dredged material disposal and over time will have reduced capacity, necessitating the location of new disposal areas. The beach-quality sediment contained within these disposal sites was originally part of the estuarine and oceanfront beach system, and removal of the material from these littoral systems has had an unknown impact on the habitat value of the estuarine and oceanfront communities. Compared to undisturbed marine areas, dredging of these disposal areas to restore beach-quality sediments back to their original system is likely to minimize impacts to the offshore marine benthos. Thus the Service recommends that:

13) The ODMDS and nearshore disposal sites should be targeted for dredging before undisturbed marine areas, provided that the material is ecological compatible with the native sediments of Bogue Banks’ beaches and free of toxicants.

Similar to Recommendation 10, the level of disturbance to the beach fauna may be further minimized by not directly placing fill within lands in conservation. Fort Macon State Park and the state park/regional access in Indian Beach could serve as ecological refuge(s) for beach fauna during fill construction. These relatively undisturbed areas (within the federal shore protection project) could then serve as recruitment populations for adjacent, filled areas. The fill template could be designed such that there are more abrupt transitions adjacent to these refuge areas instead of the usual tapered transitions. Natural redistribution of the fill material by wind and waves will generate accretion in the refuge areas, so they would be afforded some level of protection from storm-induced erosion. The natural accretion should minimize ecological impacts because the beach infauna presumably will be able to adapt to the natural influx of sediment easier than fill brought in via a dredge slurry and bulldozer. Consequently, the Service recommends that the Corps' project team evaluate the following:

14) Avoid filling conservation lands in the project area, allowing the natural drift of fill material into those areas instead of direct burial and manipulation by heavy equipment.

Faunal impacts to the dredge site may also be minimized by adjusting the construction methods and schedules. Shallower cuts are assumed to have less ecological impacts than deep cuts on the marine seafloor because alterations to the substrate, sedimentation, wave and current energy will be less. If the proposed dredge site is large, as the Dare County Beaches (Bodie Island) Project is at 7 square miles, limiting the excavation to small areas within the dredge site may reduce cumulative and long-term ecological impacts. Each dredging cycle could target a different portion of the dredge site, minimizing the frequency of disturbance and allowing longer benthic recovery times. Therefore the Service recommends that:

15) The construction methods and schedule should minimize the depth and spatial area dredged in any given dredging cycle to allow ecological recovery of the dredge site and offset long-term, cumulative impacts to the benthos.

Measures to Mitigate for Unavoidable Ecological Impacts

Specific compensatory mitigation measures will be recommended based upon specific project design features. In general, the Service would consider the following items as potential mitigative measures for a large-scale beach fill project. We encourage the Corps' project team to look for mitigation opportunities as the project design is formulated and evaluated.

16) If inlet shoal habitats are to be disturbed by sediment dredging, restoration of dredged material islands elsewhere within or adjacent to the inlet complex may mitigate diminished or lost functions and values to fish and wildlife resources and their dependent human uses.

17) If inlet or estuarine habitats are to be disturbed by sediment dredging, restoration of SAV areas in accordance with methods developed by the National Oceanic and Atmospheric Administration (NOAA) may mitigate diminished or lost aquatic spawning and rearing functions and values.

18) If an artificial dune or levee system is part of the preferred beach fill template, the purchase of property parcels or conservation easements along the oceanfront over time (i.e., the 50 year life of the project) if structures are destroyed by major storm events may mitigate for the long-term loss of the natural dune system by allowing the landward translation of the template over time.

19) If an artificial dune or levee system is part of the preferred beach fill template, the purchase of permanent, rolling construction and/or conservation easements between the mean high water line and the seaward edge of commercial and residential structures may

mitigate for impacts to the dry beach, dune toe and dune face habitats by allowing for the elimination of private or local beach scraping activities.

20) If elevated turbidity levels will result from the dredge and fill activities, one compensatory mitigation option is the creation of oyster reefs to offset impacts to degraded water quality and biological productivity.

21) If bird and sea turtle nesting habitat will be disturbed, restricting beach driving to non-nesting seasons (November 16 to March 1) and visible beach lighting during the nesting season (April 15 to November 15) may offset impacts to the quality of nesting habitat by enhancing the nesting environment.

Finally, long-term, scientifically rigorous, monitoring of evaluation species and their habitats may mitigate for the uncertainty associated with the long-term, potentially permanent, ecological impacts by allowing for future remedial measures based upon the findings of the monitoring. For example, documentation of the elimination of the local commercial beach fishery harvest would suggest future compensatory mitigation to the local fishermen. If the fill material is ecologically compatible with the native beach sediments of the project area, however, the ecological impacts may be inferred from similar projects elsewhere in the state. In that case, the monitoring should be designed specifically to answer remaining scientific questions. Some of these questions may include:

- Can benthic intertidal invertebrates be successfully collected ahead of the dredge pipeline and placed on new fill material behind the dredge pipeline? If so, does this result in quicker recovery of the beach ecosystem?
- Does the introduction of higher carbonate content within fill material significantly delay recovery of the beach by invertebrates, birds and fish as compared to beach fill without an increase in carbonate content?
- Do high carbonate contents within fill material significantly increase the permeability, porosity and resistence to wave and wind transport of the substrate? If so, how does that effect habitat quality for micro-, meio-, and macrofauna, and sea turtle nesting?
- What is the rate of bleaching of darker fill sediments on North Carolina beaches, and how deep does bleaching occur within the substrate? Does the bleaching alter the geochemistry of the substrate?
- Does the heavy mineral content of beach sediments adversely alter the geochemistry and gas diffusion rates of sediments at the depth of sea turtles nests?
- Do the native sands of North Carolina beaches (i.e., heavy mineral sands versus quartz sands) have significantly different heat capacities and therefore temperatures relevant to incubating sea turtles?
- Is the nutrient cycling within the beach sediments significant to filter-feeding benthos, and if so, how does a beach fill project alter the nutrient cycle?
- Is grain shape and/or roundness important to sandy beach invertebrates? Is the burrowing ability and/or burrow stability of ghost crabs significantly altered with different grain size distributions and compositions?
- Is there an aquatic seed bank of seabeach amaranth seeds that is responsible for

increased numbers of the plant following dredged material disposal activities?

- At what water depth and burial depth do coquina clams and mole crabs overwinter in offshore waters?
- Is the foraging efficiency (e.g., caloric intake per unit effort) of shorebirds decreased following a beach fill project, and if so, for how long?
- Does the short-term increase in turbidity within the surf zone and nearshore during and immediately following a dredged material disposal operation adversely impact fishery and benthic resources?

Due to the variety of unanswered scientific questions regarding the ecological impacts of beach fill projects, we recommend that:

22) If the beach fill material is ecologically compatible with the native beach sediments of the project area, the monitoring program should target remaining scientific questions and means to hasten ecological recovery of the project area.

SECTION 11. SUMMARY AND POSITION OF THE SERVICE

Bogue Banks is a complex barrier island composed of old beach ridges and dune fields (Moslow and Heron 1994; Riggs 2002). The island is not dominated by overwash processes, having some of the highest interior elevations of any North Carolina barrier islands instead. The maritime forest and freshwater wetland communities within this high dune ridge and swale topography are of high value (resource category of 2) to fish and wildlife resources. The estuarine shoreline and Bogue Sound also provide high value (resource category of 2) to fish, shellfish, and wildlife resources in the project area, containing waters designated as ORW in the western portion of Bogue Sound and as a HAPC throughout the sound. Bogue Inlet to the west is of high value (resource category of 2) due to its scarcity as a comparably undisturbed tidal inlet in North Carolina. Beaufort Inlet to the east of the island is disturbed by a deep navigational channel and regular maintenance dredging, reducing its value to a more abundant, high to medium value (resource category of 3) to fish and wildlife resources. The nearshore and offshore marine areas are of high value (resource category of 2) to commercially and recreationally important fisheries, hardbottoms, artificial reefs, marine mammals, sea turtles and a productive benthic community.

A dredge and fill project to stabilize the oceanfront shoreline of Bogue Banks is more likely to be successful than for most other locations in North Carolina. The habitat value of the potential beach fill area is medium to low (resource category of 4), and several dredge and fill projects are occurring already. Relatively low erosion rates and high island elevation create a more durable system for beach nourishment than other low-lying, overwash-dominated barrier islands in the state.

Although adverse environmental impacts can result from dredge and fill projects, many of these impacts can be avoided and minimized. Conducting the dredge and fill activities during the period of lowest biological productivity (December to March 1), avoiding biologically productive inlet shoulders and previously undisturbed seabeds, utilizing a design template that capitalizes on natural aeolian and vegetative processes to restore foredune habitats, and potentially recycling ecologically compatible sediments from the nearshore and offshore disposal sites are all conservation measures that would avoid and minimize environmental impacts.

For those impacts that cannot be avoided, mitigation measures are available to offset those impacts. Reductions in biological productivity resulting from increases in turbidity during the dredge, fill and fill reworking processes can be offset by a mitigation project elsewhere in Carteret County such as oyster reef restoration. Reductions in habitat value for nesting birds and sea turtles can be offset by restricting beach driving to the period between November 16 and March 1 when neither of these resources are nesting. Reducing the level of light reaching the beach from nearby structures during sea turtle nesting season (April 15 to November 15) will also benefit successful sea turtle nesting. Finally, a monitoring plan that includes both physical and biological parameters would evaluate the success of avoidance and minimization measures and could offset remaining uncertainties and unanticipated impacts. A project management team that includes the monitoring contractors, resource agencies, the local sponsor and the Corps could oversee the construction and operations and maintenance of the project and determine when ecological impacts are no longer anticipated and determine when the monitoring should be discontinued. The team could also adaptively guide the project if unanticipated events occur (e.g., dredging tires, taking sea turtles).

Implementation of the conservation measures recommended within this report should create an ecologically sound shore protection project for Bogue Banks that avoids and minimizes damages to fish and wildlife resources. A dredge and fill project that utilizes ecologically compatible fill materials and avoids disturbing new seabeds would be the least environmentally damaging alternative and one we would support. Avoiding known fishing grounds and beach seining seasons would minimize damages to the local fishing industry, as would minimizing impacts to the prey base for those fishery resources. If these measures could be implemented, the Service would support a dredge and fill project on Bogue Banks.

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APPENDIX A. Acronyms that may appear in the text.

AIWW:	Atlantic Intracoastal Waterway
ASMFC:	Atlantic States Marine Fishery Commission
CBRA:	Coastal Barrier Resources Act
CBRS:	Coastal Barrier Resources System
CEQ:	Council on Environmental Quality
CRC:	Coastal Resources Commission
DOI:	Department of the Interior
DOQQ:	Digital Orthophoto Quarter Quad (an aerial image of one-quarter of a topographic quandrangle)
EFH:	Essential Fish Habitat
HAPC:	Habitat Area of Particular Concern
HQW:	High Quality Water (a water quality designation by the NC DWQ)
LIDAR:	Light Detection and Ranging
MAFMC:	Mid-Atlantic Fishery Management Council
MHW:	Mean High Water
MLLW:	Mean Lower Low Water
MLW:	Mean Low Water
Mr. SID:	A proprietary name for color infrared digital orthophoto quarter quad images
NCCF:	North Carolina Coastal Federation
NC DCM:	North Carolina Division of Coastal Management
NC DMF:	North Carolina Division of Marine Fisheries

NC DWQ:	North Carolina Division of Water Quality
NC WRC:	North Carolina Wildlife Resources Commission
NED:	National Economic Development
NEPA:	National Environmental Policy Act
NERR:	National Estuarine Research Reserve
NGVD:	National Geodetic Vertical Datum
NMFS:	National Marine Fisheries Service
NOAA:	National Oceanic and Atmospheric Administration
ODMDS:	Offshore Dredged Material Disposal Site
OPA:	Otherwise Protected Area (a designation under the CBRA)
ORW:	Outstanding Resource Water (a water quality designation by the NC DWQ)
SAFMC:	South Atlantic Fishery Management Council
SAV:	Submerged aquatic vegetation
UNC-IMS:	University of North Carolina at Chapel Hill, Institute of Marine Sciences
USACE:	U.S. Army Corps of Engineers
US EPA:	U.S. Environmental Protection Agency
USFWS:	U.S. Fish and Wildlife Service
USGS:	U.S. Geological Survey
USMMS:	U.S. Minerals Management Service

APPENDIX B. Federally-listed Species List for Carteret and Onslow Counties

CARTERET COUNTY

Common Name	Scientific Name	Status
Vertebrates		
American alligator	*Alligator mississippiensis*	T(S/A)
Bachman's sparrow	*Aimophila aestivalis*	FSC
Black rail	*Laterallus jamaicensis*	FSC
Bogue Banks endemic skipper	*Atrytonopsis sp1*	FSC
Carolina gopher frog	*Rana capito capito*	FSC
Eastern painted bunting	*Passerina ciris ciris*	FSC*
Eastern cougar	*Felis concolor couguar*	Endangered*
Green sea turtle	*Chelonia mydas*	Threatened
Hawksbill turtle	*Eretmochelys imbricata*	Endangered
Henslow's sparrow	*Ammodramus henslowii*	FSC
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
West Indian Manatee	*Trichechus manatus*	Endangered
Mimic glass lizard	*Ophisaurus mimicus*	FSC
Northern diamondback terrapin	*Malaclemys terrapin terrapin*	FSC
Piping Plover	*Charadrius melodus*	Threatened
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Roseate tern	*Sterna dougallii*	Endangered
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Southern hognose snake	*Heterodon simus*	FSC*
Invertebrates		
a skipper (butterfly)	*Atrytonopsis sp1*	FSC
Arogos skipper	*Atrytone arogos arogos*	FSC
Carter's noctuid moth	*Spartiniphaga carterae*	FSC
Croatan crayfish	*Procambarus plumimanus*	FSC
Venus flytrap cutworm moth	*Hemipachnobia subporphyrea subporphyrea*	FSC
Vascular Plants		
Carolina asphodel	*Tofieldia glabra*	FSC
Carolina goldenrod	*Solidago pulchra*	FSC
Chapman's sedge	*Carex chapmanii*	FSC
Dune bluecurls	*Trichostema sp. 1*	FSC
Loose watermilfoil	*Myriophyllum laxum*	FSC

Pondspice	*Litsea aestivalis*	FSC
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Endangered
Savanna cowbane	*Oxypolis ternata*	FSC
Seabeach amaranth	*Amaranthus pumilus*	Threatened
Venus flytrap	*Dionea muscipula*	FSC
Nonvascular Plants		
Savanna campylopus	*Campylopus carolinae*	FSC

ONSLOW COUNTY

Common Name	Scientific Name	Status
Vertebrates		
American alligator	*Alligator mississippiensis*	T(S/A)
Bachman's sparrow	*Aimophila aestivalis*	FSC
Bald eagle	*Haliaeetus leucocephalus*	Threatened (Proposed for delisting)
Black rail	*Laterallus jamaicensis*	FSC
Carolina gopher frog	*Rana capito capito*	FSC
Eastern cougar	*Felis concolor couguar*	Endangered
Eastern painted bunting	*Passerina ciris ciris*	FSC*
Green sea turtle	*Chelonia mydas*	Threatened
Henslow's sparrow	*Ammodramus henslowii*	FSC
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Mimic glass lizard	*Ophisaurus mimicus*	FSC
Piping Plover	*Charadrius melodus*	Threatened
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Southern hognose snake	*Heterodon simus*	FSC
Invertebrates		
Croatan crayfish	*Procambarus plumimanus*	FSC
Vascular Plants		
Awned meadowbeauty	*Rhexia aristosa*	FSC
Boykin's lobelia	*Lobelia boykinii*	FSC
Carolina asphodel	*Tofieldia glabra*	FSC
Carolina goldenrod	*Solidago pulchra*	FSC
Carolina grass-of-parnassus	*Parnassia caroliniana*	FSC
Carolina spleenwort	*Asplenium heteroresiliens*	FSC
Chapman's sedge	*Carex chapmanii*	FSC

Cooley's meadowrue	*Thalictrum cooleyi*	Endangered
Golden sedge	*Carex lutea*	Proposed endangered
Hirst's panic grass	*Dichanthelium sp. 1*	FSC
Loose watermilfoil	*Myriophyllum laxum*	FSC
Pondspice	*Litsea aestivalis*	FSC
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Endangered
Savanna cowbane	*Oxypolis ternata*	FSC
Seabeach amaranth	*Amaranthus pumilus*	Threatened
Spring-flowering goldenrod	*Solidago verna*	FSC
Thorne's beaksedge	*Rhynchospora thornei*	FSC
Venus flytrap	*Dionea muscipula*	FSC

KEY:

Status	Definition
Endangered -	A taxon "in danger of extinction throughout all or a significant portion of its range."
Threatened -	A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
Proposed -	A taxon proposed for official listing as endangered or threatened.
C1 -	A taxon under consideration for official listing for which there is sufficient information to support listing.
FSC -	A Federal species of concern--a species that may or may not be listed in the future (formerly C2 candidate species or species under consideration for listing for which there is insufficient information to support listing).
T(S/A) -	Threatened due to similarity of appearance (e.g., American alligator)--a species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.
EXP -	A taxon that is listed as experimental (either essential or nonessential). Experimental, nonessential endangered species (e.g., red wolf) are treated as threatened on public land, for consultation purposes, and as species proposed for listing on private land.

Species with 1, 2, 3, or 4 asterisks behind them indicate historic, obscure, or incidental records:

* Historic record - the species was last observed in the county more than 50 years ago.

** Obscure record - the date and/or location of observation is uncertain.

*** Incidental/migrant record - the species was observed outside of its normal range or habitat.

**** Historic record - obscure and incidental record.

Critical Habitat in Carteret and Onslow Counties

Piping Plover overwintering habitat:

"Unit NC-8: Shackleford Banks. 716 ha (1769 ac) in Carteret County. The entire unit is within Cape Lookout National Seashore. This unit is in two parts: (1) The eastern end of Shackleford Banks from MLLW of Barden Inlet extending west 2.4 km (1.5 mi), including Diamond City Hills, Great Marsh Island, and Blinds Hammock; and, (2) The western end of Shackleford Banks from MLLW extending east 3.2 km (2.0 mi) from Beaufort Inlet. The unit includes all land from MLLW to where densely vegetated habitat, not used by the piping plover, begins and where the constituent elements no longer occur and any emergent sandbars within Beaufort Inlet. This unit is bordered by Onslow Bay, Shackleford Slue, and Back Sound." (Federal Register 66(132):36067)

"Unit NC-9: Rachel Carson. 445 ha (1100 ac) in Carteret County. The entire unit is within the Rachel Carson National Estuarine Research Reserve. This unit includes islands south of Beaufort including Horse Island, Carrot Island, and Lennox Point. This unit includes entire islands to MLLW." (Federal Register 66(132):36067)

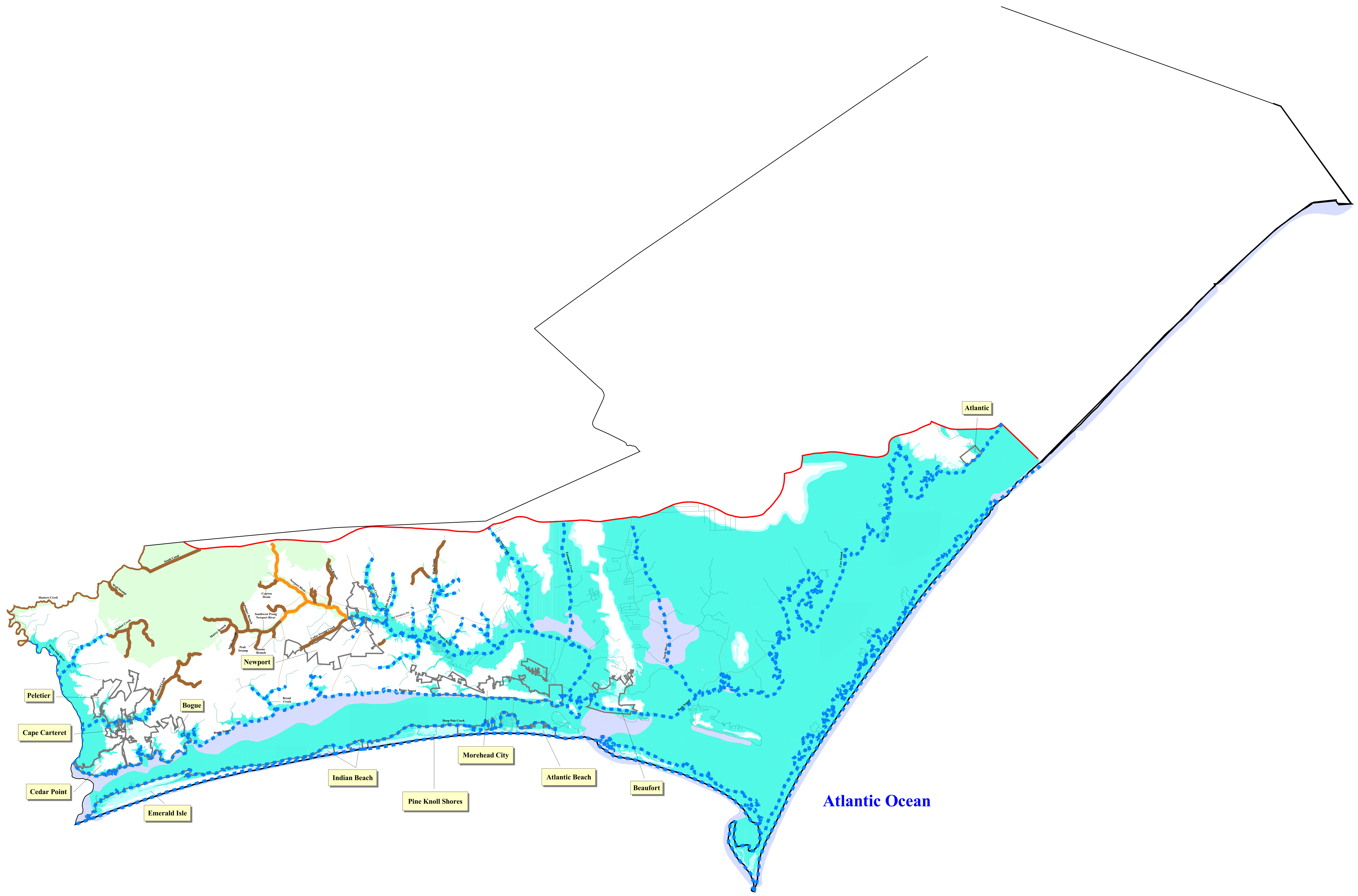
"Unit NC-10: Bogue Inlet. 143 ha (354 ac) in Carteret and Onslow Counties. The majority of the unit is privately owned, with the remainder falling within Hammocks Beach State Park. This unit includes contiguous land south, west, and north of Bogue Court to MLLW line of Bogue Inlet on the western end of Bogue Banks. It includes the sandy shoals north and adjacent to Bogue Banks and the land on Atlantic Ocean side to MLLW. This unit also extends 1.3 km (0.8 mi) west from MLLW of Bogue Inlet on the eastern portion of Bear Island." (Federal Register 66(132):36067)

APPENDIX C. Updated Flood Insurance Rate Maps (FIRMs) for Carteret and Onslow Counties

Final Basin Plan

White Oak River Basin

Carteret County North Carolina (Attachment E)



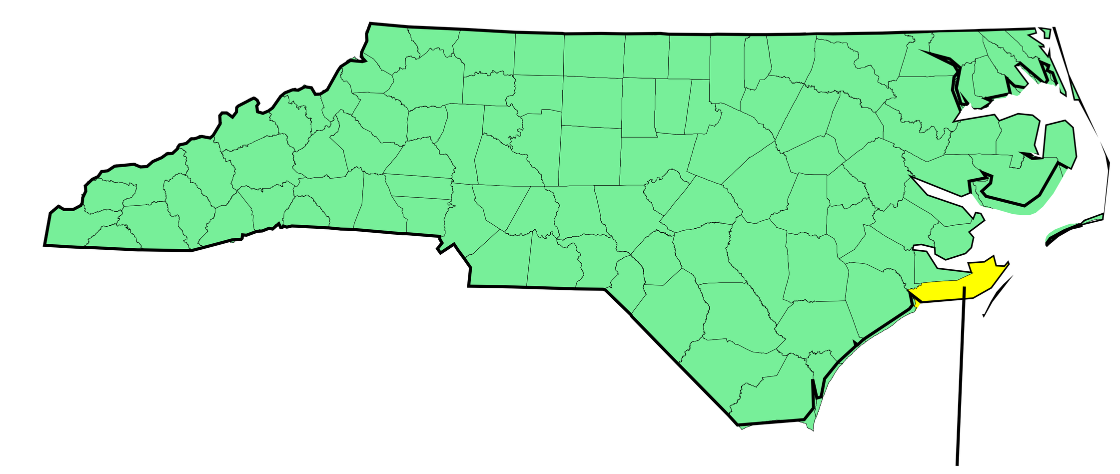
Legend

Recommendation

- Approximate study
- Detailed study coastal
- Detailed study riverine
- Redelineate with updated topography

- County Boundary
- Community Boundary
- Watershed Boundary
- Stream/Shoreline
- Road
- 1% Annual Chance (100-Year) Floodplain with Base Flood Elevation (BFE)
- 0.2% Annual Chance (500-Year) Floodplain
- 1% Annual Chance (100-Year) Approximate Floodplain
- Coastal Flood Velocity Hazard with Base Flood Elevation (BFE)

North Carolina Locator Map



Data Sources

NHD and NC State Stream Data
FEMA Q3 Flood Hazard Data
NC State Community Boundaries
NC State County Boundaries
NC State River Basin Boundaries

N W E S

20000 0 20000 40000 60000 Feet

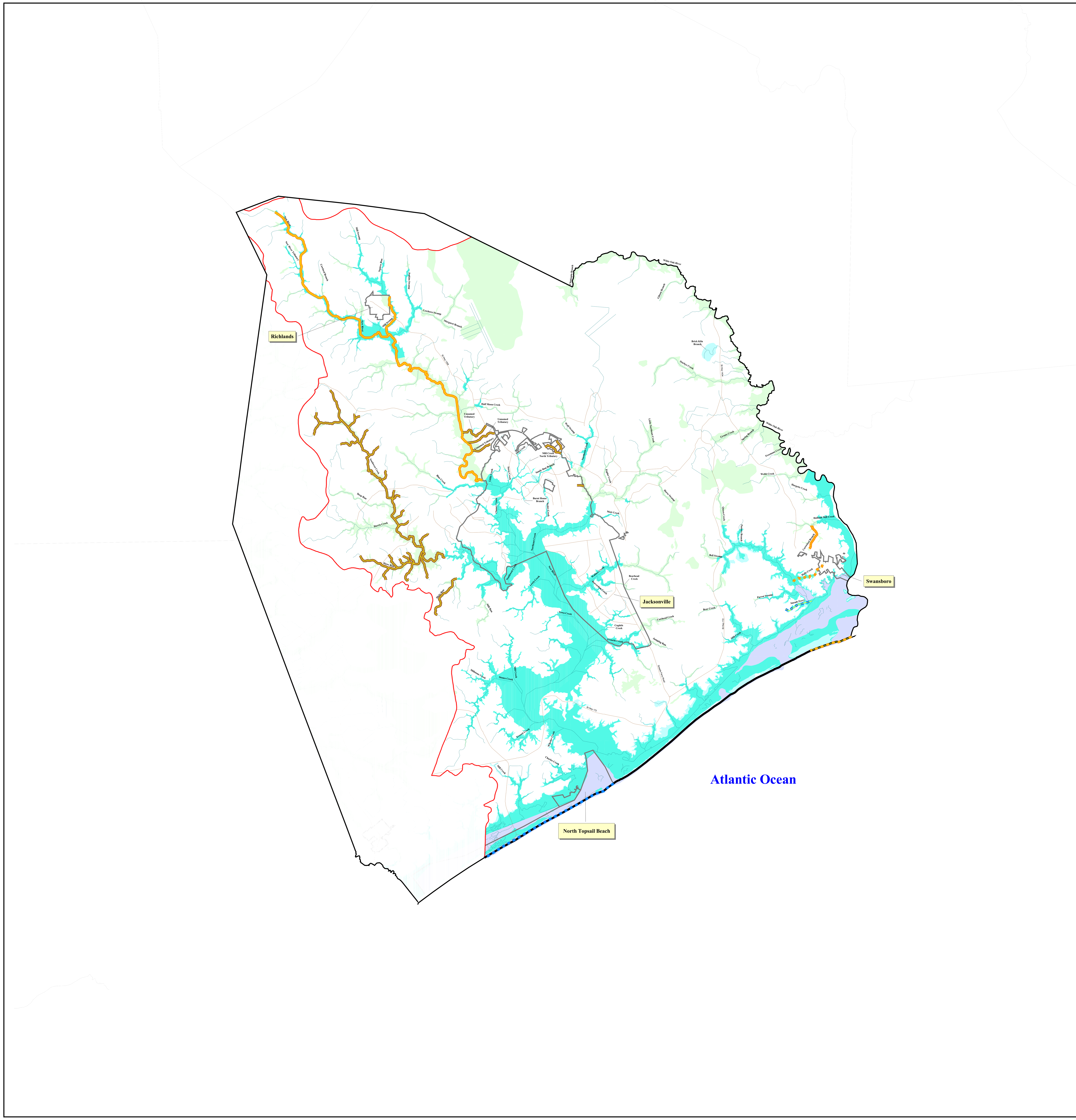
Prepared for the:

State of North Carolina and the
Federal Emergency Management Agency
June 22, 2001

Prepared by:

Dewberry & Davis LLC
A Dewberry Company

Community Recommendations
White Oak River Basin
Onslow County North Carolina (Attachment D)



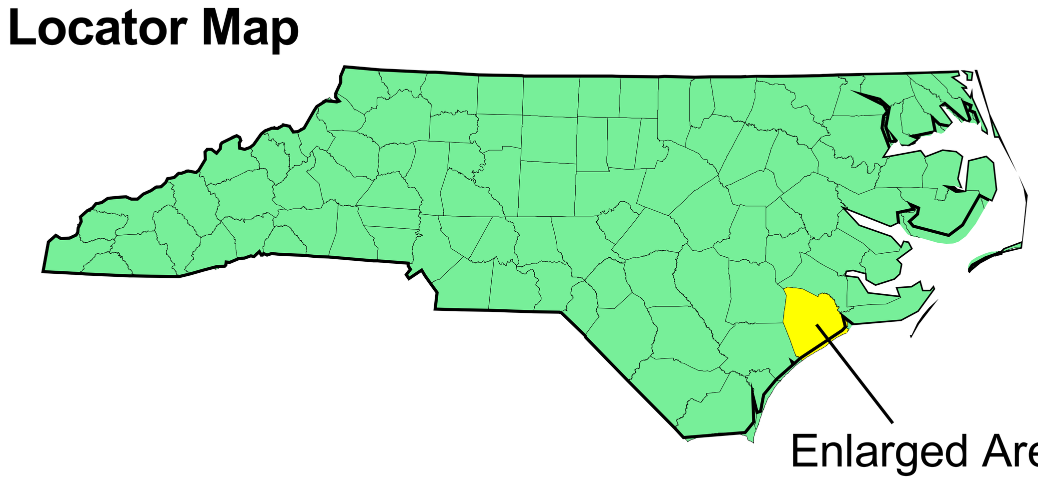
Legend

Recommendation
- Approximate study
- Detailed study coastal
- Detailed study riverine
- Redelineate with updated topography

Community Priority Level
- High
- Medium
- Low

- Community Boundary
- County Boundary
- Watershed Boundary
- Stream/Shoreline
- Road
- 1% Annual Chance (100-Year) Floodplain with Base Flood Elevation (BFE)
- 0.2% Annual Chance (500-Year) Floodplain
- 1% Annual Chance (100-Year) Approximate Floodplain
- Coastal Flood Velocity Hazard with Base Flood Elevation (BFE)

North Carolina Locator Map



Data Sources

NHD and NC State Stream Data
FEMA Q3 Flood Hazard Data
NC State Community Boundaries
NC State County Boundaries
NC State River Basin Boundaries

N W E S

20000 0 20000 40000 Feet

Prepared for the:

State of North Carolina and the Federal Emergency Management Agency
June 22, 2001

Prepared by:

Dewberry & Davis LLC
A Dewberry Company

APPENDIX D. North Carolina Migratory Shorebird Microhabitat Availability in 1998

Color infrared orthophoto one-quarter quadrangle images, in digital format, taken of eastern North Carolina by the U.S. Geological Survey (USGS) in 1998 were analyzed for six migratory shorebird and waterbird microhabitat types. The study area started at the Virginia-North Carolina boundary in the north and proceeded south to Hog Inlet, the first tidal inlet entirely within South Carolina.

The six microhabitats were defined as bare sand areas with differing hydrologic and geomorphic characteristics. The microhabitat categories and remote survey methodology were reviewed by a group of ornithologists and technical experts at the 2002 Piping Plover, Southern Recovery Unit, Meeting held in Chincoteague, Virginia, in January. A brief summary of each microhabitat is summarized below.

(1) *wet inlet shoulder*. These areas are intertidal in nature and occur along the shorelines immediately adjacent to tidal inlets. This microhabitat represents a foraging habitat with an infaunal community dominated by polychaete worms and amphipods. Only inlets open in 1998 were evaluated.

(2) *dry inlet shoulder*. Immediately adjacent to wet inlet shoulder microhabitats, these areas occur above the visible wet-dry line and represent nesting, roosting and loafing habitat. Dry inlet shoulder areas ceased to exist where vegetation became more than sparse.

(3) *ebb tidal shoal*. Sandy shoal areas within the ebb tidal delta of inlets that were interpreted as emergent at mean low water (intertidal) or shallow enough for use by wading birds were categorized as ebb tidal shoals. Water depths for consideration were less than one foot and were interpreted by best professional judgement. Ebb and flood tidal shoals represent staging areas for migrating flocks, roosting and foraging areas.

(4) *flood tidal shoal*. Sandy shoal areas within the flood tidal delta of inlets that were interpreted as emergent at mean low water (intertidal) or shallow enough for use by wading birds were categorized as flood tidal shoals. Water depths for consideration were less than one foot and were interpreted by best professional judgement. Flood tidal shoals tend to be dominated by an amphipod and polychaete infaunal community whose structure depends on the magnitude of tidal currents and waves. Flood tidal shoals occasionally support submerged aquatic vegetation (SAV), with its associated high aquatic habitat value, on their leeward side.

(5) *tidal creeks and flats*. Areas within tidal creeks that had filled with emergent or shallow sand shoals were classified in this microhabitat. Tidal creeks were present on the estuarine portion of barrier islands or within estuarine marsh complexes. Sandy intertidal or shallow flats contiguous with the estuarine shoreline were also placed in this category. This microhabitat represents a quieter foraging environment with proximity to fauna found in muddy substrates (i.e., adjacent marshes), small fish, crustaceans, shellfish, etc.

(6) *overwash-dominated beach*. Sections of barrier islands, generally those devoid of

development, where overwash processes dominate the distribution of bare sand habitats were categorized as overwash-dominated beach. These areas were defined by overwash terraces, fans and flats that penetrated the visible dune line or stable vegetation. Some overwash-dominated beach reaches extended from the oceanfront to the sound shoreline. Inlets that had recently closed were placed in this category because tidal influences were no longer present. This microhabitat predominantly represents nesting habitat.

Using the Geographic Information System (GIS) software ArcView 3.2a, the microhabitats were digitally traced where they occurred along the barrier islands and tidal inlets along the Atlantic Ocean. The spatial area (in acres) of each microhabitat was tabulated for each barrier island and inlet where habitat was present. Best professional judgement and experience with each location surveyed served as a ground-truthing of conditions present during 1998. The digital boundaries between microhabitats were traced at a 1:4000 scale with an estimated accuracy of ±10 feet. Acreage calculations are conservative given the different days and tidal stages of adjacent images.

Table D-1 lists the total of all six microhabitats for each tidal inlet complex, in order of decreasing acreage. Table D-2 lists the specific microhabitat acreage for each closed inlet location (for inlets closed within the last 40 years), again in decreasing abundance. Table D-3 provides the total acreage for overwash-dominated beach habitats. The final table, Table D-4, summarizes the coverage of each microhabitat for each geographic area, proceeding from south to north along the North Carolina coast.

Table D-1. Total area at each inlet complex within the six microhabitat categories, listed in order of decreasing area. See Table D-4 for a break-down of the areas within each microhabitat.

Inlet Complex	Area (acres)
Ocracoke	1176.72
New Drum	772.20
Oregon	670.88
Cape Fear River[1]	627.98
New River	560.16
Beaufort	462.78
Barden	446.52
Bogue	436.76
New Topsail	433.65
Hatteras	431.79
Bear	283.07
Hog	209.93
Shallotte[2]	136.71
Tubbs	133.15
Mason	105.12
Brown	100.41
Lockwood's Folly	91.18
Rich	89.42
Little River	87.42
Carolina Beach	76.78
Masonboro	45.67

[1] Note the totals for the Cape Fear River mouth include habitat on or adjacent to Battery Island.
[2] Note the totals for Shallotte Inlet are incomplete due to an unavailable quarter-quad of 1998 color-infrared aerial imagery.

Table D-2. Total identifiable area at each closed inlet complex within the six microhabitat categories, listed in order of decreasing area. The year in which the inlet closed and whether the inlet closed naturally or artificially is also listed. See Table D-4 for a break-down of the areas within each microhabitat.

Closed Inlet Complex	Year Inlet Closed	Type of Closure	Area (acres)
New (Corncake)	1998-99	Natural	249.24
Old Topsail	1998	Natural	159.64
Mad	1997	Natural	71.61
Old Drum	1998	Natural	0
Moore's	1965	Artificial	0
Buxton	1963	Artificial	0

Table D-3. Locations with significant overwash-dominated beach microhabitat, listed in order of decreasing abundance.

Location	Area (acres)
Portsmouth Island	3228.25
Core Banks	821.57
Shackleford Banks	459.64
Masonboro Island	401.75
Cape Lookout	328.41
Smith Island (area south of New/Corncake Inlet)	295.77
Fort Fisher (area north of New/Corncake Inlet)	226.52
Cape Hatteras	206.42
Lea Island	98.50
Carolina Beach	69.49
Hutaff Island	69.08
Cape Fear	19.91

Table D-4. The spatial coverage of each microhabitat for each location surveyed between the Virginia-North Carolina state line and Hog Inlet, South Carolina. The locations are presented from south to north.

	Microhabitat						
Location	Flood tidal shoals	Ebb tidal shoals	Dry inlet shoulder	Wet inlet shoulder	Tidal creek shoals/flats	Overwash-dominated beach	Total
Hog Inlet	18.32	5.33	14.33	56.71	3.19	112.05	209.93
Little River Inlet	70.96	0	11.87	4.59	0	0	87.42
Mad Inlet (closed)	0	0	0	0	0	71.61	71.61
Tubbs Inlet	66.97	4.19	5.93	47.63	8.43	0	133.15
Shallotte Inlet[1]	0	28.21	32.68	29.83	0	45.99	136.71
Lockwood's Folly Inlet	12.3	0	42.58	36.3	0	0	91.18
Cape Fear River[2]	467.93	46.43	47.47	47.06	19.09	0	627.98
Cape Fear	0	0	0	0	0	19.91	19.91
Smith Island	0	0	0	0	0	295.77	295.77
New Inlet (closed)	10.17	0	0	0	0	239.07	249.24
Fort Fisher	0	0	0	0	0	226.52	226.52
Carolina Beach	0	0	0	0	0	69.49	69.49
Carolina Beach Inlet	0	1.49	51.69	20.57	3.03	0	76.78
Masonboro Island	0	0	0	0	0	401.75	401.75

Location	Flood tidal shoals	Ebb tidal shoals	Dry inlet shoulder	Wet inlet shoulder	Tidal creek shoals/flats	Overwash-dominated beach	Total
Masonboro Inlet	21.75	0	19.33	4.59	0	0	45.67
Moore's Inlet (closed)	0	0	0	0	0	0	0
Mason Inlet	36.84	0	(inc. in overwash category)	(inc. in overwash category)	0	68.28	105.12
Rich Inlet	35.23	0	37.02	17.17	0	0	89.42
Lea Island	0	0	0	0	0	98.5	98.5
Old Topsail Inlet (closed)	99.3	0	0	0	19.69	40.65	159.64
Hutaff Island	0	0	0	0	0	69.08	69.08
New Topsail Inlet	189.75	31.81	83.74	52.17	76.18	0	433.65
New River Inlet	48.69	50.57	54.11	55.02	0	351.77	560.16
Brown Inlet	5.29	0	26.25	30.58	0	38.29	100.41
Bear Inlet	119.62	31.51	47.5	71.06	13.38	0	283.07
Bogue Inlet	175.67	45.62	103.05	83.54	28.88	0	436.76
Beaufort Inlet	227.26	0	43.77	79.04	112.71	0	462.78
Shackleford Banks	0	0	0	0	142.38	317.26	459.64
Barden Inlet	160.37	17.37	22.11	86.23	160.44	0	446.52
Cape Lookout	0	0	0	191.65	0	136.76	328.41
Old Drum Inlet (closed)	0	0	0	0	0	0	0

Location	Flood tidal shoals	Ebb tidal shoals	Dry inlet shoulder	Wet inlet shoulder	Tidal creek shoals/flats	Overwash-dominated beach	Total
Core Banks	0	0	0	0	408.81	412.76	821.57
New Drum Inlet	472.88	0	95.89	192.45	10.98	0	772.2
Portsmouth Island	0	0	0	0	2523.09	705.16	3228.25
Old Drum Inlet[3]	0	0	0	0	0	0	0
Ocracoke Inlet	621.4	29.18	129.57	396.57	0	0	1176.72
Hatteras Inlet	215.35	0	110.55	105.89	0	0	431.79
Cape Hatteras	0	0	0	45.87	0	160.55	206.42
Buxton Inlet (closed)	0	0	0	0	0	0	0
Oregon Inlet	401.1	0	71.59	198.19	0	0	670.88
TOTALS	**3477.15**	**291.71**	**1051.03**	**1852.71**	**3530.28**	**3881.22**	**14,084.10**

[1] Note the totals for Shallotte Inlet are incomplete due to an unavailable quarter-quad of 1998 color-infrared aerial imagery.
[2] Note the totals for the Cape Fear River mouth include habitat (classified as flood tidal shoal microhabitat) on or adjacent to Battery Island.
[3] Note that Old Drum Inlet had closed and no longer had a distinctive geomorphology by the time of the 1998 imagery. The inlet re-opened in 1999 during Hurricanes Dennis and Floyd.

APPENDIX E. Commercial Fisheries Landings Data for the Project Area, 1994 - 2001. Data are from the NC DMF and exclude confidential data.

Table E-1 summarizes the commercial fishery landings for the White Oak River and Bogue Inlet area, listing the total pounds of each species caught within that area for years between 1994 and 2001. Landings with no data listed show that the data are confidential, indicating a low number of fishermen reporting catches in those categories for that year.

Landings category	1994	1995	1996	1997	1998	1999	2000	2001
other/f	5,750	9,837	4,509	4,747	1,944	1,277	508	367
other/s	5,603			434		56	109	
bluefish	172	361		317	944	90	116	
cobia								
catfishes						72	56	147
croaker	99	73		51	161	132	329	137
cutlassfish, atlantic								
dolphinfish								
black drum	94	548	4,304	295	227	370	1,181	382
red drum	470	986	693	189	818	4,213	1,252	817
common eel								
southern flounder	8,356	9,261	12,465	20,431	15,905	25,765	13,638	11,044
king mackerel								
kingfishes			179			24		
menhaden bait								
minnow								
mullet	11,447	18,708	15,258	9,890	26,435	10,005	27,232	30,686
pigfish			108	71	138			
pompano					10			
gray seatrout	107	22		6	86	15		262
spotted seatrout	2,304	1,800	1,011	872	723	1,970	1,363	1,234
shad, unclassified								
sharks								
sheepshead	45	34		34	60	81	108	143
spanish mackerel				85	18		51	
spot	8,969	28,713	12,234	3,991	5,841	142,843	9,622	16,238
white perch								
striped bass								

yellowfin tuna								
unclassified for food								
uncl. For industrial or bait								
hard blue crab	130,848	99,431	92,276	69,721	141,195	157,186	112,649	153,323
peeler blue crab		10,239	5,105	10,283	12,114	16,520	16,265	19,557
soft blue crab	168	1,341	1,686	146	3	51		4
stone crab	309	37	246	544	244	70		127
horseshoe crab								
shrimp, unclassified	45,019	39,311	23,825	12,986	23,582	4,600		
brown shrimp						1,572	9,076	6,094
white shrimp						31,812	53,053	
pink shrimp								56,218
hard clams	36,036	34,057	22,246	21,264	19,003	25,535	21,933	49,154
arc clams		1,529	1,016	525	556	132	133	426
whelks/conchs	271	52	69					31
eastern oyster	4,818	2,931	847	2,459	566	448	698	3,371
bay scallop								
squid, unclassified								

Table E-2 summarizes the commercial fishery landings for Bogue Sound, listing the total pounds of each species caught within that area for years between 1994 and 2001. Landings with no data listed show that the data are confidential, indicating a low number of fishermen reporting catches in those categories for that year.

Landings category	1994	1995	1996	1997	1998	1999	2000	2001
other/f	18,009	1701	1003	2731	305	4251	2309	250
other/s	1403	111			2468		2870	
amberjack	0		0		0	0		0
barracuda	0	0	0	0	0	0	0	0
bluefish	1603	2700	2960	3879	6584	1545	6013	4439
bonito	0	0	0		0	0	0	0
butterfish	1061	395	808		21		109	
cobia				0		0	0	0
catfishes	0		0					0
crevalle (jacks)	0				0	0	0	0
croaker	1354	1215	667	962	262		1294	642
cutlassfish, atlantic			45	918		209		
dolphinfish	0	0	0	0	0	0	0	0
drum, black	130	1000	3350	559	157	774	772	757
drum, red	590	3936	11,291	746	551	2647	2844	1056
eel, common	0		0	0	0	0	0	0
flounder, southern	11,414	23,292	14,640	19,468	15,122	16,393	28,859	23,713
gag grouper	0	0		0	0	0	0	0
grunts	0	0		0	0	0	0	0
hakes, Atlantic, unclassified	0			0	0		0	0
harvestfish								0
mackerel, king	0						0	0
kingfishes (sea mullet)	139	1531	244	487	153	2241	1458	189
ladyfish	0	0	0		0	0	0	
menhaden bait	6462	6875	10,486	3620	3516	5862	11,850	11,957
minnow	0	907	2800	3459	2871	1758		1772
mullets	99,361	175,282	45,156	139,239	98,090	30,733	158,882	165,507
rosefish, blackbelly		0	0	0	0	0	0	0
escolar		0	0	0	0	0	0	0

parrotfish	0	0	0		0	0	0	0
pigfish	1650	944	1001	1883	898	977	485	260
pompano					37		23	72
sea basses, unclassified	0	0		0	0	0	0	0
seatrout, gray	743	1840	2111	544	774	2831	477	610
seatrout, spotted	6115	13,411	5841	4471	7279	8201	7372	2785
shad, hickory	0		2982		0	0	0	0
shad, unclassified	0	0			0	0	0	0
shark, thresher	0	0		0	0	0	0	0
shark, dogfish, smooth	0		0	0	0	0	0	0
sharks		0	1829				0	
sheepshead	288	1235	258	448	20	441	457	452
snapper, vermilion	0		0	0	0	0	0	0
spadefish, Atlantic	0					0	0	
spanish mackerel	514	3158	3795	2834	3429	4617	9073	637
spot	48,988	117,989	50,695	21,600	28,773	87,155	100,617	85,148
swellfishes (puffers)		0		103		0		0
perch, yellow	0			0	0	0	0	0
perch, white		0		0	0	0	0	0
striped bass	0	0		0	0	0	0	0
triggerfish	0			0	0	0	0	0
tripletail	0	0	0		0	0	0	0
tuna, little	0	0	0		0		0	0
tuna, yellowfin	0		0	0	0	0	0	0
tuna, unclassified	0			0	0	0	0	0
unclassified for food	145		262	202	0		514	490
uncl. for industrial or bait		17,889	1671					
wahoo	0		0	0	0	0	0	0
blue crab, hard	261,909	178,282	272,190	195,123	211,821	151,166	212,494	159,684
blue crab, peeler	2580	5213	5842	4824		2201		
blue crab, soft	447	955	1338					405
stone crab		1606	1268	389	409	106		166
horseshoe crab	0		0	0	0	0	0	0
shrimp, unclassified (heads on)	23,344	34,345	45,689	17,009	41,849	5527		
shrimp, brown	N/A	N/A	N/A	N/A	N/A	401	13,436	7059
shrimp, white	N/A	N/A	N/A	N/A	N/A	42,292	7094	2393

shrimp, pink	N/A	N/A	N/A	N/A	N/A	0	2650	383
clams, hard (meats)	42,798	47,086	27,897	32,799	31,857	27,869	32,603	44,183
clams, arc	134	527	191	237	217	116	147	91
clams, rangia	0		0	0	0	0	0	0
clams, sunray venus (meats)		0	0	0	0	0	0	0
whelks/conchs (meats)	4653	1667	2171	1079	1640	1435	1236	2194
oyster, eastern	423	3061	2761	8720	5964	8461	11,965	10,841
scallop, bay	2763	6418	5922	21,150	30,551	21,792	20,753	633
squid, short-finned	0	0		0		0	0	0
squid, unclassified			0	0	0	0	0	0

Table E-3 summarizes the commercial fishery landings for the Newport River and Beaufort Inlet area, listing the total pounds of each species caught within that area for years between 1994 and 2001. Landings with no data listed show that the data are confidential, indicating a low number of fishermen reporting catches in those categories for that year.

Landings category	1994	1995	1996	1997	1998	1999	2000	2001
other/f	7800	1994	707	4130	242	1659	6904	5613
other/s	20,716	19,891	25,247	235	14,821	100	346	23
bluefish	266	125	195	2467	167	91	228	91
bonito	0		0		0	0	0	0
butterfish	0				0	0	0	0
carp	0	0	0	0	0		0	0
catfishes	0	0	0	0	0		0	0
cobia				0	0	0	0	0
crevalle (jacks)	0	0	0		0	0	0	0
croaker	456	248	159	3659		86	19	46
cutlassfish, atlantic	0			753	0	154		0
dolphinfish	0	0	0	0	0	0	0	0
drum, black	77		407	92		305	241	173
drum, red	126	111	1117	290	880	1924	1343	923
eel, common	0	0	0	0	0	0	0	
flounder, southern	12,758	4226	11,223	14,976	11,923	7891	13,664	12,028
garfish			0	0	0	0	0	0
harvestfish			0			188	0	0
mackerel, king	0	0	0	0	0	0	0	0
kingfishes (sea mullet)		332	177	920	0	50	21	
ladyfish	0	0	0		0	0	0	0
menhaden bait		0						
minnow	0		1845	4436	2484	1852		10,855
mullets	13,356	7132	5495	33,985	24,250	27,284	31,801	33,647
rosefish, blackbelly	0	0	0	0	0	0	0	0
escolar		0	0	0	0	0	0	0
pigfish			63	50		88		0
pompano		0		0	9			
sea basses, unclassified	0			0	0	0	0	0

seatrout, gray	44	49	104	787	61	315		15
seatrout, spotted	752	418	306	559	474	839	100	193
shad, unclassified	0	0	0		0	0	0	0
sharks	0	0	0		0	0	0	0
sheepshead	44			127	111	38	162	69
skippers	0	0	0	0		0	0	0
spadefish, Atlantic	0	0	0	0		0	0	0
spanish mackerel	1855	0		494	46	7	41	0
spot	3467	5011	2663	15,288	2501	15,407	3000	7108
swellfishes (puffers)	0	0			0	0		0
perch, white	0	0	0		0	0		0
striped bass	0	0	0	0	0	0	0	0
toadfishes	0	0	0		0	0	0	0
tripletail			0		0	0		
tuna, little	0	0	0		0	0	0	0
tuna, yellowfin	0	0	0	0	0	0	0	0
unclassified for food	184		0			0		
uncl. for industrial or bait		0	0		0	0	0	
blue crab, hard	376,303	314,232	330,894	382,214	443,067	364,911	231,567	201,491
blue crab, peeler				20,101		23,848	21,566	28,390
blue crab, soft		91			0	44		
stone crab	158	1061			18		0	
horseshoe crab	0	0	0	0	0	0	0	0
shrimp, unclassified (heads on)	166,380	275,058	125,092	213,818	71,793	78,610	312	
shrimp, brown	N/A	N/A	N/A	N/A	N/A	33,980	71,818	43,954
shrimp, white	N/A	N/A	N/A	N/A	N/A	194,492	168,118	130,909
shrimp, pink	N/A	N/A	N/A	N/A	N/A	422	335	1613
shrimp, rock		0	0	0	0	0	0	0
clams, hard (meats)	45,064	74,197	76,051	84,978	90,799	70,483	57,223	77,394
clams, arc	0		0	0	0	0		0
clams, sunray venus (meats)	0	0	0	0	0	0	0	0
whelks/conchs (meats)	735	332	809	369	163			622
oyster, eastern	15,428	13,829	12,897	12,996	7257	6158	6515	16,587
scallop, bay		1312	0			179		0
squid, short-finned	0	0	0	0	0	0	0	0
squid, unclassified		0		0	0	25	53	0

Table E-4 summarizes the commercial fishery landings for the marine area south of Cape Hatteras from 0 to 3 miles offshore, listing the total pounds of each species caught within that area for years between 1994 and 2001. Landings with no data (denoted by "–") listed show that the data are confidential, indicating a low number of fishermen reporting catches in those categories for that year.

	Landings (lbs)							
Species	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
AMBERJACKS	984.64	544.08	1578.8	1307.26	358.04	–	268.28	–
ANGELFISHES	0	–	0	–	0	0	0	0
ANGLERFISH (GOOSEFISH)	1152	–	7774.5	–	1359	631	–	917
BARRACUDA	81.4	0	–	0	–	0	0	0
BIGEYE	–	–	0	–	–	0	0	0
BLUEFISH	19,038.41	28,415.46	48,703.67	92,584.83	97,267.03	15,359	23,257.75	26,538.75
BLUERUNNER	–	0	–	–	–	0	0	0
BONITO	315	–	–	11,350	10,795	4556	848.5	435
BUTTERFISH	12,185.85	59,192	42,862.3	40,184	11,993.5	12,481	14,608	19,094
CATFISHES	0	–	0	–	–	–	–	0
CLAM, HARD (MEATS)	65.772	–	0	0	0	0	0	0
COBIA	974.125	553.25	1091.875	925.75	1015.4	–	185	275
COD	0	0	0	–	0	0	0	0
CRAB, BLUE, HARD	9579	1228.99	501	–	–	–	0	–
CRAB, HORSESHOE	0	0	0	0	0	–	0	0
CRAB, BLUE, PEELER	0	–	0	–	0	–	0	0
CRAB, STONE	0	–	0	–	–	–	0	0
CREVALLE (JACKS)	–	0	–	304.32	243	–	0	0
CROAKER	85,334.9	154,741.6	1,077,185	636,158.6	291,379.7	166,303	135,621	180,596
CUTLASSFISH, ATLANTIC	0	541.24	–	–		–	–	–
DOLPHINFISH	–	134.16	–	855.92	346.2	–	–	–
DRUM,BLACK	141.8	9261.3	1996.5	1372	101	731	299	396.5
DRUM,RED	412.6	9518.5	7994	2479.6	–	–	1135	1653.5
EEL, CONGER	413.8	–	0	–	–	–	–	0
FLOUNDER< GRAY SOLE	0	0	0	0	–	0	0	0
FLOUNDERS, SUMMER	28,089.65	144,514.75	498,106	25,378.17	288,444.2	132,112.1	46,881.4	92,748
GIZZARD SHAD	0	0	0	–	0	0	0	0

GROUPER, BLACK	0	0	–	0	0	0	0	0
GROUPER, GAG	1815.38	660.25	1220.5	1825.325	696.45	–	615	–
GROUPER, RED	– 0	–	86.25	–	109.38	–	–	–
GROUPER, SCAMP	–	–	77.75	–	–	0	–	0
GROUPER, SNOWY	–	0	–	–	–	0	0	–
GROUPER, UNCLASSIFIED	–	–	–	0	0	0	0	0
GROUPER, YELLOWEDGE	–	0	0	0	0	0	0	0
GRUNTS	–	125.5	68	23.5	86	–	–	0
HAKE	0	0	0	0	0	0	–	0
HARVESTFISH	1235.5	–	2218.5	2418	3966.16	7246	1625	–
HERRING, THREAD	–	–	–	–	–	0	–	0
HICKORY SHAD	–	0	–	–	–	1475	–	–
HIND, RED	0	–	–	–	–	0	0	0
HOGFISH	0	–	–	0	–	0	0	0
KINGFISHES (SEA MULLET)	47,197.87	275,520.64	150,776	224,096.3	59,409.9	193,198.3	149,518.2	93,208.7
LADYFISH	0	–	–	–	1400	–	–	–
LAMPREY	0	–	0	0	0	0	0	0
MACKEREL, ATLANTIC	0	0	–	0	0	0	0	23,816
MACKEREL, KING	2757.696	1597.528	2785.46	14,255.48	15,642.57	1212.96	1921.92	2679.94
MACKEREL, SPANISH	30,960.72	4497.8	15,985.4	64,479.39	43,345.62	28,737.92	32,874.4	40,543.85
MARGATE	518	52	–	–		0	0	0
MENHADEN	68,248,030	55,581,860	52,848,930	93,306,880	54,783,070	40,147,610	52,718,580	53,130,418
MENHADEN BAIT	420,525.48	78,660	108,672.96	150,716.7	318,671	399,427.5	96,178.8	245,784.5
MINNOWS	–	–	–	0	0	0	0	0
MULLETS	227,226.19	144,823.2	79,448.5	281,863.1	188,191	30,313	321,104.6	199,576.7
OCTOPUS	–	214.5	–	0	–	–	–	–
OYSTER, EASTERN	–	0	0	0	0	0	0	0
PERCH, OCEAN	0	0	–	0	0	0	0	0
PERCH, WHITE	0	0	0	0	0	0	–	0
PIGFISH	1611	6697	2893.5	1514.15	976	923	2211.2	203
PINFISH	–	0	–	0	0	0	0	0
POMPANO	111.9	144.3	–	5197	573	357.5	882.9	209.9
POMPANO, AFRICAN	0	0	0	0	0	–	–	0
PORGIES, UNCLASSIFIED	0	–	–	0	–	0	0	0
PORGY, KNOBBED	29	–	–	–	58	–	0	0
PORGY, RED	266.38	–	330	–	250.81	–	0	0

PORGY, SPOTTAIL	0	–	0	–	53.3	0	–	0
SCALLOP, SEA (MEATS)	–	0	21	0	0	–	–	–
SEA BASSES, UNCLASSIFIED	6555.1	1144.8	0	570.75	2328.8	142.5	976	–
SEATROUT, GRAY	283,510.75	185,340.3	2618.35	660,212.2	333,101	311,460.7	23,963.5	24,657
SEATROUT, SPOTTED	14,070.15	15,939.45	700,211.2	17,998.62	6220	7652.5	4608	3422.5
SHAD, UNCLASSIFIED	–	–	3398.5	–	–	–	–	0
SHARK, BLACKTIP	0	–	–	0	0	0	0	0
SHARK, BONITO (SHORTFIN MAKO)	0	–	0	–	0	0	0	–
SHARK, ATLANTIC SHARPNOSE	0	0	0	0	0	0	0	–
SHARK, DOGFISH, SMOOTH	590.3	–	0	–	19,270	–	–	0
SHARK, DOGFISH, SPINY	0	–	–	294615	400,950	–	–	0
SHARK, HAMMERHEAD	–	0	155,741	0	0	0	0	0
SHARK, THRESHER	0	0	0	–	–	0	0	0
SHARKS	8923.3	4431.2	–	13,065	5570.5	439.7	–	–
SHEEPSHEAD	2001.3	809	4732.4	4092	1551	1374.5	1265	698
SHRIMP, BROWN	N/A	N/A	N/A	N/A	N/A	34,631.18	56,118.44	32,706.48
SHRIMP, WHITE	N/A	N/A	N/A	N/A	N/A	361,070.1	1,932,859	67,246.32
SHRIMP, PINK	N/A	N/A	N/A	N/A	N/A	0	–	3909
SHRIMP, ROCK	–	–	2652	–	0	0	0	0
SHRIMP, UNCLASSIFIED (HEADS ON)	155,638.87	250,926.78	4161	172,890.7	344415	49,643.33	–	0
SKATES	0	–	318,430.12	0	0	0	0	0
SKIPPERS	0	–	0	0	–	–	0	0
SNAPPER, MUTTON	0	–	0	–	0	0	0	0
SNAPPER, RED	–	–	0	52.22	–	–	0	–
SNAPPER, UNCLASSIFIED	–	0	583.2	0	0	0	0	0
SNAPPER, VERMILION	1138	402.19	–	448.85	137.21	–	0	0
SPADEFISH, ATLANTIC	–	–	602.1	–	–	592	0	–
SPOT	158,916	390,651.65	0	127567.7	268,932.3	189,519	311,443.5	454,164.5
SQUID, SHORT-FINNED	0	3168	224,973.16	649	449	0	–	0
SQUID, UNCLASSIFIED	1103.3	10,669	2471.4	–	2246	2040	3127.5	467
STRIPED BASS	–	–	2796	–	–	–	–	14,858
SWELLFISHES (PUFFERS)	2464	5975	–	–	–	–	1554	–
SWORDFISH	–	0	4462	0	–	0	0	0
TAUTOG	0	–	0	0	–	–	0	0
TILEFISH	0	0	0	–	0	0	0	0
TILEFISH, BLUELINE	–	0	0	–	–	0	0	0

TILEFISH, SAND	0	–	–	–	0	0	0	0
TRIGGERFISH	779.05	1393.5	0	896.3	309	–	–	–
TUNA, BLACKFIN	–	0	829.5	–	–	0	0	0
TUNA, BLUEFIN	0	0	0	0	0	0	0	–
TRIPLETAIL	0	0	–	–	0	0	0	0
TUNA, BIGEYE	0	0	–	–	0	0	0	0
TUNA, LITTLE	–	266	–	1737	3674	2934	3310	5885.6
TUNA, YELLOWFIN	–	0	1207	1774.95	–	–	–	–
TUNA, UNCLASSIFIED	0	–	–	–	0	0	0	0
UNCL. FOR INDUSTRIAL USE OR BAIT	2975	6866	–	89,384	4501	30,949	–	–
UNCLASSIFIED FOR FOOD	111	7253	38,445	456	1970	1847	507	0
WAHOO		–	1275	520.73	613.6	–	–	213.2
WHELKS/CONCHS (MEATS)	–	–	614.64	–	–	0	0	0

Table E-5 summarizes the commercial fishery landings for the marine area south of Cape Hatteras from greater than 3 miles offshore, listing the total pounds of each species caught within that area for years between 1994 and 2001. Landings with no data listed show that the data are confidential, indicating a low number of fishermen reporting catches in those categories for that year.

	Landings (lbs)							
Species	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
AMBERJACKS	47,860.71	55,598.76	57,183.74	55,510.82	50,777.82	66,583.24	65,881.87	64,419.78
AMERICAN JOHN DORY	0	0	0	0	–	0	0	0
ANGELFISHES	–	–	0	–	–	0	0	0
ANGLERFISH (GOOSEFISH)	46,807	60,434.20	25,903.00	0	17,087.00	15,170.00	4444.00	9829.75
BARRACUDA	2703.5	1772.60	1135.10	855.10	1453.29	760.21	1125.75	0
BARRELFISH	0	0	–	–	0	0	–	–
BIGEYE	180.1	60.80	713.00	968.50	714.70	1413.45	697.50	1335.00
BLUEFISH	21,297.98	4490.35	34,188.42	62,911.07	30,390.17	40,157.83	11,495.31	36,031.50
BLUERUNNER	322.7	251.90	45.70	–	80.00	51.00	0	–
BONITO	–	132.80	–	16481.00	1970.00	5614.00	–	479.00
BUTTERFISH	36,931.9	24,714.00	23,156.00	46,393.00	6063.00	12322.10	2397.00	2542.00
CATFISHES	0	0	0	0	0	0	0	0
CLAM, HARD (MEATS)	0	0	0	0	0	0	0	0
COBIA	3501.19	9538.34	3523.38	3106.95	2574.63	2396.38	1925.00	2101.63
COD	–	13.90	–	–	–	–	–	0
CRAB, BLUE, HARD	–	0	0	–	0	0	0	0
CRAB, HORSESHOE	0	–	0	0	0	0	0	–
CRAB, BLUE, PEELER	0	0	0	–	0	0	0	0
CRAB, STONE	0	–	0	0	0	0	0	0
CREVALLE (JACKS)	0	–	–	–	235.00	–	–	–
CROAKER	637,212	759,195.00	515,993.00	2,287,072.05	1,840,819.00	1,330,622.75	823,092.00	1,006,835.00
CUTLASSFISH, ATLANTIC	0	0	0	0	0	0	–	0
DOLPHINFISH	22,231.59	84,818.27	23,107.33	23,961.22	22,545.66	35,231.87	30,157.04	45,564.05
DRUM,BLACK	773	4867.15	594.00	–	885.50	–	616.00	–
DRUM,RED	762	160.00	–	275.00	0	–	–	0
EEL, COMMON	–	–	0	0	0	0	0	0
EEL, CONGER	1918.9	1263.18	1216.30	1087.90	441.90	885.30	1345.85	1277.50
FLOUNDER, BLACKBACK	0	0	–	0	0	0	0	0

FLOUNDER, GRAY SOLE	–	14,200.00	–	0	–	–	–	0
FLOUNDERS, SUMMER	723,694.2	1,461,539.25	1,199,358.14	657,563.30	622,753.30	567,649.20	768,391.50	645,734.00
GROUPER, BLACK	–	–	–	0	0	–	0	0	0
GROUPER, GAG	102,051	82,720.49	51,203.39	71,108.56	66,351.98	55,785.19	46,774.19	77,966.63
GROUPER, GRAYSBY	0	0	–	0	0	0	0	0
GROUPER, MARBLED	–	0	–	0	0	0	–	0
GROUPER, MISTY	0	0	–	0	0	0	0	0
GROUPER, RED	16,878.79	29,291.55	22,213.00	20,199.88	44,895.81	63,664.00	55,327.88	48,732.44
GROUPER, SCAMP	16,085	25,573.13	15,432.50	14,625.25	16,891.88	20,629.25	17,754.88	15,661.44
GROUPER, SNOWY	35,416.28	43,614.35	63,243.63	73,820.13	54,628.06	491,17.38	455,363.38	47,362.81
GROUPER, UNCLASSIFIED	250	432.23	240.75	1478.88	–	–	177.50	652.50
GROUPER, VELVET (CREOLE-FISH)	–	0	0	36.25	–	0	0	0
GROUPER, WARSAW	–	0	0	0	0	0	0	0
GROUPER, YELLOWEDGE	–	–	–	–	0	0	–	0
GROUPER, YELLOWFIN	1321.25	311.50	429.25	–	483.75	482.50	493.75	190.00
GRUNTS	17956.2	14226.75	6854.40	7144.06	10477.85	8550.40	6382.35	6071.85
HAKE, ATLANTIC, UNCLASSIFIED	374	949.50	262.30	96.60	138.00	–	–	–
HARVESTFISH	–	323.00	0	9397.00	1604.00	–	–	302.00
HERRING, THREAD	0	0	0	0	–	–	0	0
HICKORY SHAD	0	0	–	0	–	0	0	0
HIND, RED	4154.13	6228.53	3775.94	2897.94	4388.06	3867.63	2288.69	2028.19
HIND, ROCK	–	0	0	0	0	–	0	0
HIND, SPECKLED	421.9	0	0	0	0	0	0	0
HOGFISH	681.75	4423.31	1339.35	1452.50	1573.63	2700.00	993.75	787.88
JACK, ALMACO	–	0	0	0	0	–	–	988.48
KINGFISHES (SEA MULLET)	174,535.5	219,421.00	64,720.00	185,981.00	36,882.93	31,155.00	11,086.00	11,973.00
LADYFISH	0	0	0	–	0	0	0	0
LAMPREY	0	0	0	0	0	0	0	0
LOOKDOWN	0	0	0	0	0	0	–	0
MACKEREL, ATLANTIC	–	0	0	–	0	–	–	–
MACKEREL, KING	61,747.15	56,660.65	33,419.68	36,448.38	60,414.74	24,974.43	38,866.00	35,713.87
MACKEREL, SPANISH	4242.63	161.90	767.50	1699.40	1845.40	1907.85	161.60	2638.60
MARGATE	13,350.35	13,379.75	6778.30	413.60	39.00	–	–	0
MENHADEN	0	0	0	–	0	0	–	0
MENHADEN BAIT	–	0	–	–	0	62,417.00	–	–

MINNOWS	0	0	0	0	0	0	0	0
MULLETS	357.8	159.60	–	–	0	0	–	–
OCTOPUS	1832.7	1722.90	531.90	212.00	129.00	91.90	349.30	156.50
OILFISH	0	0	0	0	0	0	0	1501.00
OYSTER, EASTERN	0	0	0	0	0	0	0	0
PARROTFISH	–	0	0	0	–	0	0	0
PERCH, OCEAN	231.5	81.80	664.00	125.00	360.00	–	240.00	373.00
PERCH, WHITE	0	–	0	0	0	0	0	0
PIGFISH	689	532.70	1597.20	2138.00	614.00	429.00	562.00	–
PINFISH	–	0	0	0	0	0	0	0
POLLOCK, ATLANTIC	0	–	0	0	0	0	0	0
POMPANO	364.1	533.70	88.80	0	108.00	–	–	–
POMPANO, AFRICAN	–	497.30	–	–	–	–	–	–
PORGIES, UNCLASSIFIED	3050	3704.25	789.00	–	–	–	612.25	–
PORGY, KNOBBED	1595.1	693.15	4167.30	4959.50	7087.60	6910.30	5144.60	4700.20
PORGY, RED	50,510.94	63,042.94	53,945.31	47,313.44	46,084.25	28,874.88	3,963.69	12,535.38
PORGY, SAUCEREYE	0	–	0	0	0	0	0	0
PORGY SPOTTAIL	221.47	1437.65	1133.40	5432.26	1315.90	883.10	2026.50	1353.25
PORGY, WHITEBONE	0	0	0	0	–	0	0	0
ROSEFISH, BLACKBELLY	234.8	206.60	523.40	303.90	185.00	351.00	278.00	–
RUDDERFISH, BANDED	–	–	0	0	0	0	0	–
SAND PERCH	–	175.70	–	0	–	0	0	0
SCALLOP, SEA (MEATS)	117,362.00	130,049.00	43,060.00	23,712.00	37,884.00	6,035.00	1,090.00	34,820.00
SEA BASSES, UNCLASSIFIED	51,606.84	30,090.55	43,795.35	32,346.02	26,861.75	41,177.45	56,483.41	69,784.20
SEA ROBIN	0	0	0	0	–	0	0	0
SEATROUT, GRAY	244,013.50	464,976.00	87,012.00	207,236.00	573,997.00	370,872.00	64,579.75	36,944.00
SEATROUT, SPOTTED	286	1206.00	261.00	171.00	487.00	141.70	–	–
SCUP	–	–	–	0	–	–	0	0
SHAD, UNCLASSIFIED	0	–	–	0	0	–	0	0
SHARK, BLACKTIP	–	0	–	0	–	23905.20	40650.00	–
SHARK, BONITO (SHORTFIN MAKO)	10,524.60	16,235.00	13,194.80	3,512.00	4,576.01	10,988.00	10,284.00	8,420.00
SHARK, DOGFISH, SMOOTH	3258	–	–	–	2879.00	31630.52	0	0
SHARK, DOGFISH, SPINY	–	–	–	290,709.00	167,096.00	–	0	0
SHARK, DUSKY	–	0	0	0	0	–	0	0
SHARK, HAMMERHEAD	5484	23,314.00	–	0	0	0	0	0
SHARK, LONGFIN MAKO	0	–	3140.00	0	0	0	0	0

SHARK, SANDBAR	–	0	–	0	–	195,306.00	199,414.46	–
SHARK, SAND TIGER	0	0	–	–	0	0	0	0
SHARK, THRESHER	–	–	–	0	–	11,147.00	21,562.00	0
SHARK, TIGER	7462	0	–	0	0	–	0	0
SHARKS	189,834.20	311,420.29	189,524.20	53,816.50	43,747.05	164,587.15	35,980.50	59,467.15
SHEEPSHEAD	3,780.25	3,560.00	7,205.00	1,592.00	6,036.00	3,135.00	2,689.00	3,463.00
SHRIMP, ROCK	–	–	3659.00	–	–	0	0	0
SHRIMP, UNCLASSIFIED (HEADS ON)	194,336.70	196,889.28	77,308.29	89,107.52	254,233.24	36,343.68	0	0
SHRIMP, BROWN	N/A	N/A	N/A	N/A	N/A	–	–	7566.00
SHRIMP, PINK	N/A	N/A	N/A	N/A	N/A	0	–	–
SHRIMP, WHITE	N/A	N/A	N/A	N/A	N/A	35,616.08	11,830.26	–
SKATES	–	–	0	0	0	0	0	0
SKIPPERS	0	0	0	0	–	0	0	0
SNAPPER, BLACKFIN	23.28	–	–	–	0	0	0	0
SNAPPER, CUBERA	–	73.44	–	–	–	0	–	0
SNAPPER, GRAY (MANGROVE)	–	0	–	0	0	0	0	0
SNAPPER, MUTTON	878.58	761.61	784.30	172.80	729.00	485.46	287.28	162.54
SNAPPER, RED	15,878.37	7,702.95	5,321.47	3,961.45	3,080.61	4,933.33	4,722.68	13,363.92
SNAPPER, UNCLASSIFIED	1,785.77	2,748.60	1,458.11	36.61	–	0	0	0
SNAPPER, SILK	3229.2	1165.10	0	577.80	–	1597.32	889.72	1277.64
SNAPPER, VERMILION	110,701.10	108,721.30	112,263.60	127,467.57	139,037.88	178,146.16	134,219.74	185,646.07
SNAPPER, YELLOWTAIL	172	–	–	0	–	–	–	–
SPADEFISH, ATLANTIC	–	0	–	–	–	0	–	–
SPOT	25,588.00	15,993.00	18,389.00	17,998.00	12,150.00	8,101.00	5,958.00	35,796.00
SQUID, SHORT-FINNED	0	–	899.00	–0	0	0	0	0
SQUID, UNCLASSIFIED	28,393.00	36,129.00	12,242.00	1,556.00	8,048.00	14,456.00	8,211.00	7,114.00
SQUIRREL FISHES	0	0	0	0	–	–	159.88	0
STRIPED BASS	–	2044.00	1553.00	–	–	–	14413.00	–
SWELLFISHES (PUFFERS)	7,640.75	19,616.20	19,038.60	1,077.60	4,561.00	6,760.00	–	–
SWORDFISH	1,317.31	38,397.36	37,109.56	–	55,015.20	265,338.78	236,708.85	254,302.40
TAUTOG	160.4	–	–	0	–	99.00	113.00	0
TILEFISH	4,171.43	8,383.41	–	0	596.23	337.19	713.30	–
TILEFISH, BLUELINE	5,079.95	7,362.02	11,236.81	9,476.02	8,394.64	7,320.44	7,734.38	5,542.87
TILEFISH, SAND	0	1,710.40	214.00	436.00	993.23	1,238.00	488.00	1,360.00
TOADFISHES	0	–	0	0	0	0	0	0

TRIGGERFISH	136,086.60	143,343.68	143,405.61	162,614.63	108,414.23	46,968.50	24,060.40	29,647.40
TRIPLETAIL	–	–	0	–	0	0	–	0
TUNA, ALBACORE	–	0	–	61.69	–	0	1262.03	–
TUNA, BIGEYE	–	–	11,685.27	–	–	–	–	2,710.31
TUNA, BLACKFIN	1403.75	1717.25	864.33	352.19	2,010.04	569.94	473.37	581.32
TUNA. BLUEFIN	–	0	0	0	1,935.51	0	–	–
TUNA, LITTLE	–	–	–	454.60	1,257.10	9,546.00	917.00	5,389.85
TUNA, SKIPJACK	0	0	0	–	–	0	0	0
TUNA, UNCLASSIFIED	–	–	–	–	0	0	0	0
TUNA, YELLOWFIN	25,847.74	143,714.16	50,304.52	17,051.31	41,005.47	64,478.08	67,725.83	94,829.77
TURTLES, SNAPPER	0	0	–	0	0	0	0	0
UNCL. FOR INDUSTRIAL USE OR BAIT	83180	12,991.60	0	41,942.00	–	231.00	0	0
UNCLASSIFIED FOR FOOD	–	–	2,968.00	8,812.00	4,369.50	114.00	0	220.00
WAHOO	5,265.34	11,343.16	7,961.35	4,603.96	6,337.46	7,750.29	4,333.12	7,016.10
WHELKS/CONCHS (MEATS)	2,888.72	–	0	0	–		–	–

APPENDIX F. Past, present and reasonably foreseeable future actions contributing to cumulative impacts of coastal and tidal inlet habitats between Cape Henry, VA, and Cape Romain, SC.

The effects of past, present and reasonably-foreseeable future events may have positive and negative cumulative impacts on coastal fish and wildlife resources. A preliminary list of coastal projects that may be affecting fish and wildlife resources of management concern is provided in Table F-1 as a means of scoping a cumulative effects assessment for coastal resources.

The spatial boundaries of this preliminary list span from Cape Henry, Virginia, to Cape Romain, South Carolina, because the coast between those two capes contain the overlapping breeding and overwintering ranges for several shorebirds and colonial waterbirds of very high or high management concern. This spatial area also contains the northernmost range for nesting loggerhead sea turtles and the spawning area for several fishery resources.

The temporal boundaries for this preliminary list range from the earliest construction dates of shoreline stabilization projects, through the present, to 50 years into the future (the typical planning life of a federal shore protection project). Projects are considered reasonably-foreseeable future actions (RFFA) if they have been formally proposed, environmental documents have been prepared or are being prepared, or the relevant authorization and/or permits have been obtained but construction has not started. The assumption is also made that privately sponsored projects that have occurred in the recent past and/or present are likely to continue to occur in the future. Table F-1 contains a preliminary list of these projects and actions for the purposes of scoping a cumulative effects assessment, and the list may be supplemented, edited or shortened as a full cumulative effects assessment proceeds.

The guidelines for conducting a cumulative effects assessment by the Council on Environmental Quality (CEQ) and impacts assessment literature (e.g., CEQ 1997; Canter and Kamath, 1995) suggest using a resource perspective, and for this preliminary assessment avifauna are the resource of concern. Projects or actions considered herein are those that may have had an effect (positive or negative) on the habitat for breeding, foraging, roosting and/or loafing shorebirds and waterbirds during nesting, migration and/or overwintering periods.

The types of projects or actions included in this preliminary assessment are those that have been implemented or proposed by private, local, regional, state or federal entities. Actions may include policies, plans, programs, projects or permitted events (CEQ 1997; Canter and Kamath 1995). Consequently, activities such as beach driving, waterfowl impoundments and bird exclosures are included as permitted events in individual counties, towns or national seashores, programs to enhance bird habitat, and projects to improve avian reproduction success respectively. Since bare ground areas are an important microhabitat for shorebirds and waterbirds, vegetation plantings and the artificial creation of dunes (via sand fencing or beach scraping) are included as they alter the distribution and abundance of the bare ground microhabitat. Hard stabilization projects such as seawalls, revetments, groins and jetties are included as they modify and sometimes eliminate ephemeral microhabitats (e.g., overwash fans, spits, and foredunes). Dredging projects are included to the extent that they modify tidal shoals, inlet hydrology, and inlet shoulders; inlets are a preferred habitat for many bird species. Beach nourishment or storm damage reduction projects are incorporated in the preliminary list due to their modification of oceanfront beach microhabitats for foraging, nesting and loafing.

A full cumulative effects assessment would include other resources (e.g., fishery resources, SAV, hardbottoms, marine mammals) as well. Each project or action listed in Table F-1 should be assessed for the magnitude of impact(s) relative to the other actions on each resource of concern. Impacts may be positive or negative and may be direct, indirect, incremental, additive or synergistic in origin (Canter and Kamath 1995). The assessment may rank impacts as low, medium or high magnitude if quantitative assessment methods or thresholds are not readily available. Some actions and resources may need more intensive analysis than others, and the temporal and spatial boundaries may differ for each resource.

Table F-1 provides a starting point for a cumulative effects assessment for coastal fish and wildlife resources resulting from many past, present and reasonably-foreseeable future projects and actions.

Table F-1. A preliminary list of past, present and reasonably-foreseeable future actions (RFFA) that may affect the coastal habitats of shorebirds and waterbirds. The list is presented from north to south and spans the area between Cape Henry, Virginia, and Cape Romain, South Carolina, which bracket the breeding, migratory stopover, and overwintering ranges of several shorebirds and waterbirds of concern (e.g., evaluation species in Table 4). Past events cover those of approximately the last century (the period when dredging and shoreline stabilization began), and future events include those reasonably foreseeable to occur within the next 50 years (the typical planning life of a federal shore protection project). The time period of occurrence (past, present or RFFA) is marked for each project or action, while the magnitude of the impact(s) to avifauna need to be assessed by a consensus of a resource agencies and partners.

Project	Past	Present	RFFA	Magnitude
Fort Story Geotubes	X	X		
Fort Story Revetment	X	X	X	
Virginia Beach Beach Nourishment	X	X	X	
Rudee Inlet Jetties & Dredging	X	X	X	
Dam Neck Naval Base Rock Revetment/Dune	X	X		
Dam Neck Naval Base Beach Nourishment	X			
Sandbridge Seawalls	X	X		
Sandbridge Beach Nourishment	X	X	X	
Currituck County CCC Dune Ridge	X	X		
Currituck County Beach Driving	X	X	X	
Dare County Beaches North Beach Nourishment			X	
Nags Head/Kitty Hawk Dredge Disposal		X		
Cape Hatteras National Seashore Bird Exclosures	X	X		
Bodie Island Beach Driving	X	X	X	
Oregon Inlet Dredging & Disposal	X	X	X	
Oregon Inlet Terminal Groin	X	X		
Oregon Inlet Jetties			X	
Pea Island Waterfowl Impoundments	X	X		
NC 12 Dune Maintenance - Hatteras Island	X	X	X	
Rodanthe Dredge Disposal	X			
Albemarle-Pamlico-Core Sounds Dredge Disposal Islands	X	X	X	
Avon Dredge Disposal	X			
Buxton Inlet Closure	X			
US Navy Groins	X	X		
Cape Hatteras Lighthouse Sandbags	X			
Hatteras Island Beach Driving	X	X		
Hatteras Dredge Disposal	X			
Hatteras Inlet Dredging	X	X		
NC 12 Dune Maintenance - Ocracoke Island	X	X	X	
Ocracoke Island Dredge Disposal	X		X	
Cape Lookout National Seashore Beach Driving	X	X	X	
Drum Inlet Opening & Dredging	X			
Core Banks Dredge Disposal	X			
Cape Lookout National Seashore Dune Building	X	X	X	
Vegetation Plantings on Outer Banks	X	X	X	
Barden Inlet Dredging	X			
Cape Lookout Jetty	X	X		

Project	Past	Present	RFFA	Magnitude
Shackleford Banks Jetty	X			
Beaufort Inlet Dredging	X	X	X	
Beaufort Inlet Nearshore & Offshore Disposal Sites	X	X	X	
Fort Macon Jetty & Groins	X	X		
Atlantic Beach Dredge Disposal	X	X	X	
Pine Knoll Shores Dredge Disposal	X	X	X	
Carteret Co. Bogue Banks Beach Restoration Project		X	X	
Emerald Isle Dredge Disposal	X	X	X	
Bogue Banks Beach Scraping	X	X		
Vegetation Planting in Onslow Bay	X	X	X	
Onslow Bay Dredge Disposal Islands	X	X	X	
Bogue Inlet Dredging	X	X	X	
Bogue Inlet Relocation			X	
Camp Lejeune Target Ranges	X	X	X	
Camp Lejeune Beach Nourishment			X	
Onslow Beach Dredge Disposal	X	X	X	
New River Inlet Dredging	X	X	X	
North Topsail Beach Dredge Disposal	X	X	X	
Topsail Island Dune Maintenance	X	X	X	
Topsail Island Sand Bags	X	X	X	
Topsail Island Beach Scraping	X	X	X	
Topsail Island Beach Nourishment			X	
Topsail Beach/West Onslow				
Beach Nourishment & Terminal Groin			X	
New Topsail Inlet Dredging	X	X	X	
Topsail Beach Dredge Disposal	X	X	X	
Rich Inlet Dredging	X	X	X	
Figure 8 Island Sandbags	X	X	X	
Figure 8 Island Beach Scraping	X	X	X	
Figure 8 Island Beach Nourishment	X	X	X	
Mason Inlet Relocation		X	X	
Mason Inlet Sandbag Revetment	X	X		
Wrightsville Beach Beach Nourishment	X	X	X	
Moore Inlet Closure	X			
Masonboro Inlet Jetties & Dredging	X	X		
Masonboro Inlet Channel Closure	X			
Masonboro Island Dredge Disposal	X	X	X	
Carolina Beach Inlet Opening	X			
Carolina Beach Inlet Dredging	X	X	X	
Carolina Beach Revetment	X	X		
Carolina Beach Driving	X	X		
Carolina Beach Beach Nourishment	X	X	X	
Kure Beach Beach Nourishment	X	X	X	
Fort Fisher Revetment	X	X		
Fort Fisher Driving	X	X	X	
Bald Head Island Groins (West Beach and marina)	X	X	X	
Bald Head Creek Dredging and Terminal Groin			X	
Bald Head Island Geotubes	X			
Bald Head Island Beach Scraping	X			
Bald Head Island Dredge Disposal		X	X	
Bald Head Island Beach Nourishment	X			

Project	Past	Present	RFFA	Magnitude
Cape Fear River (Wilmington Harbor) Dredging	X	X	X	
Caswell Beach-Oak Island Beach Scraping	X			
Caswell Beach-Oak Island Sandbags	X	X		
Caswell Beach Dredge Disposal		X	X	
Caswell Beach-Oak Island Vegetation planting	X	X	X	
Long Beach Sea Turtle Habitat Restoration Project		X		
Oak Island Beach Nourishment			X	
Oak Island Dredge Disposal	X	X	X	
Lockwood's Folly Inlet Dredging			X	
Holden Beach Sandbags	X	X		
Holden Beach Beach Scraping	X			
Holden Beach Dredge Disposal	X	X		
Holden Beach Beach Nourishment		X	X	
Long Bay Dredge Disposal Islands	X	X	X	
Shallotte Inlet Dredging	X	X	X	
Ocean Isle Dredge Disposal	X	X		
Ocean Isle Beach Nourishment		X	X	
Ocean Isle Beach Scraping	X			
Ocean Isle Sandbags	X	X		
Tubbs Inlet Dredging			X	
Tubbs Inlet Relocation	X			
Sunset Beach Scraping	X			
Little River Inlet Jetties	X	X		
Cherry Grove Revetment	X	X		
Hog Inlet Dredging	X	X		
North Myrtle Beach Beach Nourishment/Dredge Disposal	X	X	X	
Myrtle Beach Beach Nourishment	X	X	X	
Myrtle Beach Seawalls & Revetments	X	X		
Surfside Dredge Disposal	X	X		
Garden City Beach Nourishment	X	X	X	
Murrells Inlet Jetties	X	X		
Murrells Inlet Dredging	X	X		
Huntington Beach State Park Beach Nourishment	X			
Midway Inlet Groins	X	X		
Pawley's Inlet Dredging ?				
Pawley's Island Beach Nourishment	X			
DeBordieu Island Beach Nourishment	X			
DeBordieu Island Seawall	X	X		
Winyah Bay Mouth Dredging	X	X		
Winyah Bay Mouth (Georgetown Harbor) Jetties	X	X		
Santee River Diversion ?	X			

APPENDIX G. Preliminary Ecological Monitoring Data on the Locally-funded Bogue Banks Beach Restoration Project.

The beach fill sediments used in the Bogue Banks Beach Restoration Project were dredged during Phase I from immediately offshore of Bogue Banks and contained between 30 and 40% carbonate material. Phase II proposes to dredge sediments that average 42% carbonate material of various grain sizes. In comparison, the native beach sediments of Bogue Banks contain less than 20% carbonate material (or shells; CSE 2000). Scientists at the Institute of Marine Sciences, University of North Carolina at Chapel Hill (IMS-UNC), have tested the sensitivity of indicator fauna (coquina clams, mole crabs, and Florida pompano) to varying grain size distributions and shell content in order to better elucidate the potential impacts of sediment compatibility.

Laboratory experiments by IMS-UNC researchers testing the sensitivity of burrowing coquina clams to various sediment substrates found that the clams have slower burrowing times with increasing sediment grain sizes (Attachment G-1), confirming the findings of Alexander et al. (1993). Similar experiments with the burrowing ability of mole crabs found that burrowing times for large crabs are fastest within unsorted native beach sediments from Bogue Banks (mean grain size 0.177 mm or 2.5 phi) and significantly increase if the sediments are greater than or equal to 2 mm (-1.0 phi) or smaller than or equal to 0.0625 mm (4.0 phi; $P<0.05$; Attachment G-1). The burrowing times for small mole crabs does not significantly vary with grain sizes equal to or smaller than 1.00 mm (0.0 phi; $P<0.05$). When the sediment grain size is 4.0 mm (-2.0 phi) or greater, the time it takes a mole crab to burrow is approximately three times as long as when the sediments are unsorted natural Bogue Banks beach sands (Attachment G-1).

Experiments with shell contents ranging from the natural, unsorted content of Bogue Banks beaches to 80% shell material show that both small and large mole crabs are sensitive to increasing shell content (Attachment G-1). Significant increases in burrowing time of the crabs occur with 20% shell content as compared to the natural beach sediments of Bogue Banks ($P<0.05$; Attachment G-1). The same experiment for coquina clams indicates that their burrowing times significantly increase with 20 to 33% shell content as compared to natural concentrations on a non-nourished beach in the project area ($P<0.05$; Attachment G-1). The shell content appears to camouflage invertebrate prey from foraging fish, reducing their ability to effectively forage even when the mole crabs and coquina clams have slower burrowing times (which could make them more vulnerable to predation; Attachment G-2).

In addition to these laboratory tests, independent monitoring by the IMS-UNC is comparing the beach fill in Pine Knoll Shores and Indian Beach to control beaches in Emerald Isle. Based on this monitoring, ecological recovery of the fill has not yet occurred. This monitoring includes sampling of bird species occurrence, abundance and feeding behavior; invertebrate species occurrence and abundance (i.e., coquina clams (*Donax* sp.), mole crabs (*Emerita talpoida*), polychaete worms and amphipods); fish species occurrence and abundance; ghost crab (*Ocypode quadrata*) abundance; and physical parameters including grain size distribution and surf zone turbidity. Sampling has occurred every two months, at the ends of March, May, July and September (with data from March - July enclosed). Turbidity measurements and fish surveys were conducted in August (Attachments G-3, G-4).

The IMS-UNC monitoring results document that the abundance of shorebirds in the Phase I fill area is 85% less than control beaches, with sanderlings (*Calidris alba*), willets (*Catoptrophorus semipalmatus*), ruddy turnstones (*Arenaria interpres*), a mixture of plovers (*Charadrius* spp.), and whimbrels (*Numenius phaeopus*) the most common species (in decreasing order of abundance; Attachment G-5). There have been too few shorebirds present in the beach fill to perform a statistically valid comparison of feeding behavior (Dr. C.H. Peterson, pers. comm., September 4, 2002), so the question as to whether shorebirds can successfully forage along the 6.75 miles of Phase I beach fill remains unanswered.

The invertebrate population of the beach, which constitutes the food source for birds, ghost crabs and fish, continues to be depressed at a statistically significantly level (Attachments G-4, G-5). Coquina clams were only 20% of their undisturbed populations, and the mole crabs were depressed at a similar magnitude. Amphipod numbers were also lower on nourished sites as compared to control sites (Attachment G-5). Polychaete worms are greater in number on the beach fill than on control beaches (Attachment G-5). Preliminary data collected by Coastal Science Associates, Inc., as part of the County's biological monitoring program found a similar trend of higher numbers of polychaete worms (Attachment G-6).

The fish found in the surf zone are different in number and dominant species in the beach fill area than the control beaches, with higher numbers of baitfish (i.e., anchovy, menhaden) in the nourished areas (versus the control) and larger fish (i.e., Florida pompano, sea mullet) in the control areas (versus the nourished areas; Attachment G-4). This trend is similar to that found by USACE (2001) in New Jersey, and may reflect a species composition shift resulting from water quality differences (with visual predators preferring less turbid waters). The water clarity (or turbidity) often exceeds the state saltwater quality standard in the surf zone of the Phase I beaches while adjacent control beaches have clear water with no elevated turbidity (Attachment G-3).

On the dry part of the beach, ghost crab monitoring has documented only half the abundance of crabs in the beach fill as compared to control beaches (Attachment G-5). The populations of ghost crabs are similar on the dune face on fill and control beaches, but differ on the flat part of the beach where fill material was placed (Attachment G-5). This is probably reflective of the lack of dune disturbance during Phase I construction. Preliminary data collected by Coastal Science Associates, Inc., as part of the County's biological monitoring program sampled ghost crab burrow counts at 15 transects in Atlantic Beach (control), Pine Knoll Shores (nourished), Indian Beach (nourished), and Emerald Isle (control; Attachment G-6). Comparison of the two datasets needs to be conducted to control for differing sampling designs and summary statistics.

One beneficial outcome of the project has been the dramatic increase in numbers and sizes of seabeach amaranth (*Amaranthus pumilus*), a federally-threatened plant. The Service has not yet determined the reasons for this spectacular response and does not know if the fill material contained seeds for this plant, if the organic material provided additional nutrients, or if the beach fill created greater amounts of the plant's preferred habitat, which is foredune and overwash flat areas.

As the sediments placed during Phase I beaches have been reworked by the waves, the quartz portion of the sediments has been concentrated. This separation is visually seen as a quartz sand veneer in the swash zone, but field surveys by the Service and the Institute of Marine Sciences at the University of North Carolina at Chapel Hill (IMS-UNC) have found this veneer to be a few inches thick at most (unpubl. data). The shells that have been separated from the quartz also are concentrated by the waves at various locations within the swash zone, and may constitute up to 38% of the surface (Attachment G-4). The natural, undisturbed beaches of Bogue Banks average only 6% shell cover, indicating that the beaches of Phase I have more than 6 times the shell content on the beach surface in the swash zone (Attachment G-4).

In summary, monitoring by the IMS-UNC of Phase I of the Bogue Banks Beach Restoration Project has documented a statistically significant decline in productivity of most animals with few signs of recovery within 5 to 8 months post-construction. The abundance of indicator species does not vary significantly between areas that received fill at the beginning of Phase I (during November-December 2001) and areas that received fill at the end of Phase II (during March-April 2002; Dr. C.H. Peterson, pers. comm., September 4, 2002). As additional data becomes available from IMS-UNC and the County's biological monitoring program (with scheduled sampling periods in June and November annually), further analysis of any measured ecological impacts (positive or negative) and the existing conditions in the Bogue Banks Shore Protection Project area will be possible.

Please note that data enclosed within attachments G-1 through G-5 should not be reproduced without the written consent of the Institute of Marine Sciences, University of North Carolina at Chapel Hill.

APPENDIX H. Executive Summary of the Minerals Management Service (MMS) report *Marine Mining Technologies and Mitigation Techniques: A Detailed Analysis with Respect to the Mining of Specific Offshore Mineral Commodities*

OCS Report
MMS 95-0003

Marine Mining Technologies and Mitigation Techniques

A detailed analysis with respect to the mining of specific offshore mineral commodities

July 1996

Contract No. 14-35-0001-30723

MMS U.S. Department of the Interior
Minerals Management Service

Office of International Activities and Marine Minerals (INTERMAR)